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Yasuhara

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[45] **Oct. 26, 1982**

[54] **INJECTION ADVANCE DEVICE**

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[73] Assignee: **Nissan Motor Company, Limited**, Yokohama, Japan

[21] Appl. No.: **145,155**

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[30] **Foreign Application Priority Data**

May 1, 1979	[JP]	Japan	54-53602
Sep. 3, 1979	[JP]	Japan	54-112590
Sep. 3, 1979	[JP]	Japan	54-112591

[51] **Int. Cl.**[3] **L02M 39/00; F02M 39/00;** F02D 1/16

[52] **U.S. Cl.** **123/502;** 123/500; 123/501

[58] **Field of Search** 123/502, 501, 500

[56] **References Cited**

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Primary Examiner—Raymond A. Nelli
Attorney, Agent, or Firm—Thompson, Birch, Gauthier & Samuels

[57] **ABSTRACT**

A injection advance device is disclosed for diesel engine fuel injection pump including a pump housing, a feed pump for supplying fuel pressure proportional to engine speed into the pump chamber, and a control member movable to determine a fuel-injection timing corresponding to its position. The injection advance device comprises a casing, a cylinder reciprocally located in the casing, a piston reciprocally located in the cylinder and drivingly connected to the control member, and means for allowing movement of the piston in a direction causing the control member to advance the fuel-injection timing. Means is provided for moving the cylinder in a direction holding the piston in the position before the engine is warmed up.

13 Claims, 30 Drawing Figures

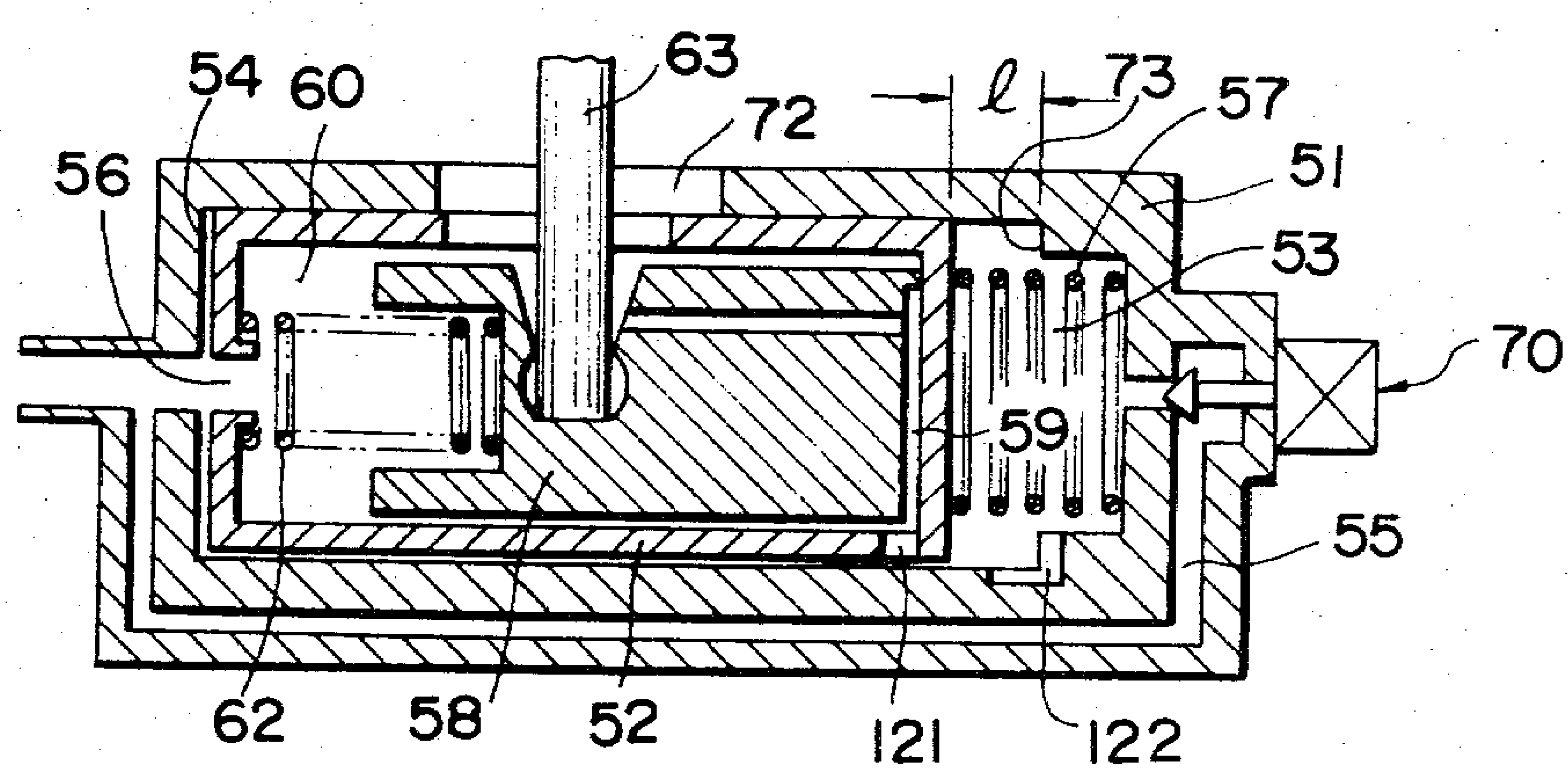

FIG. 1

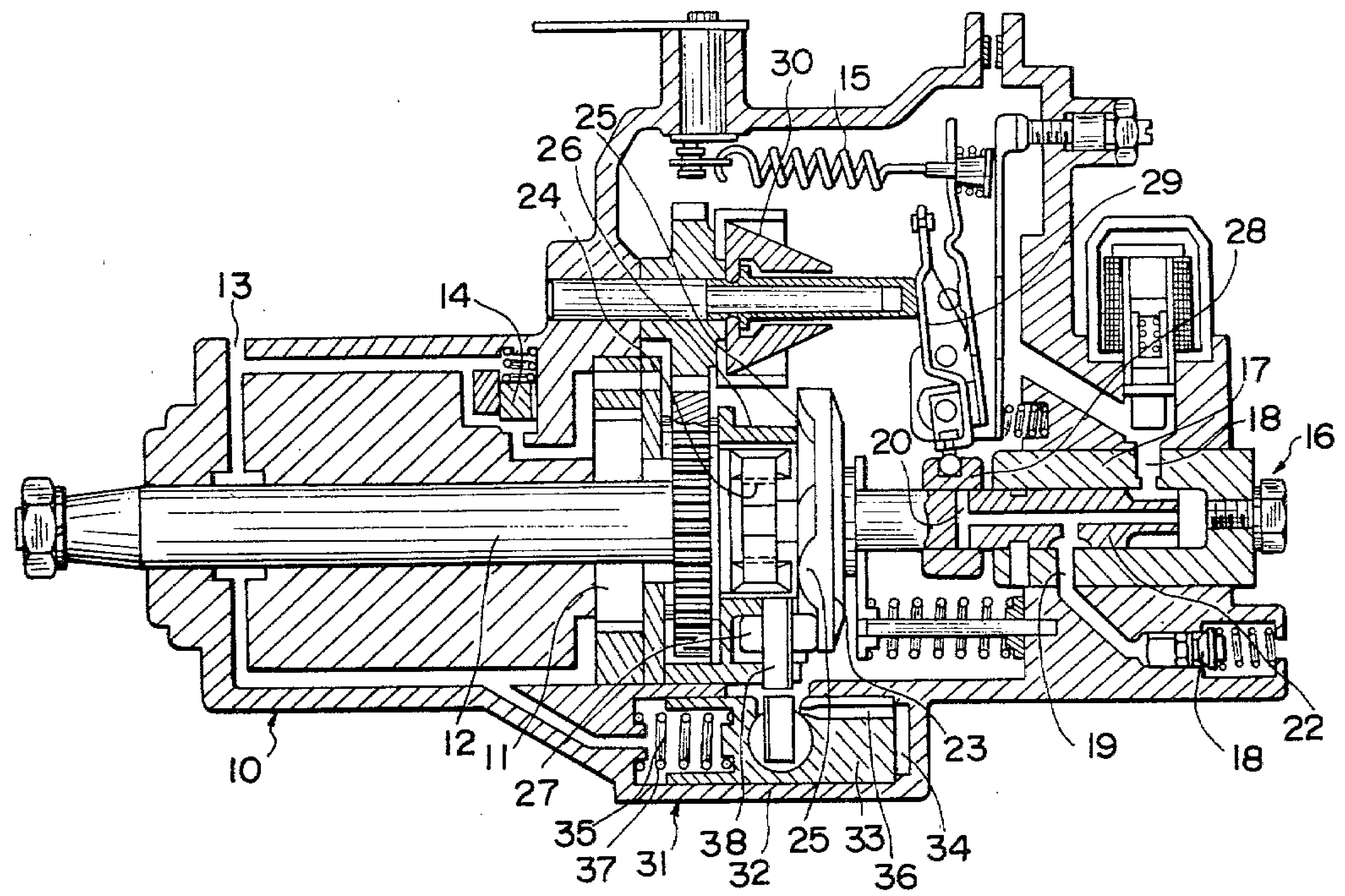
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FIG. 2

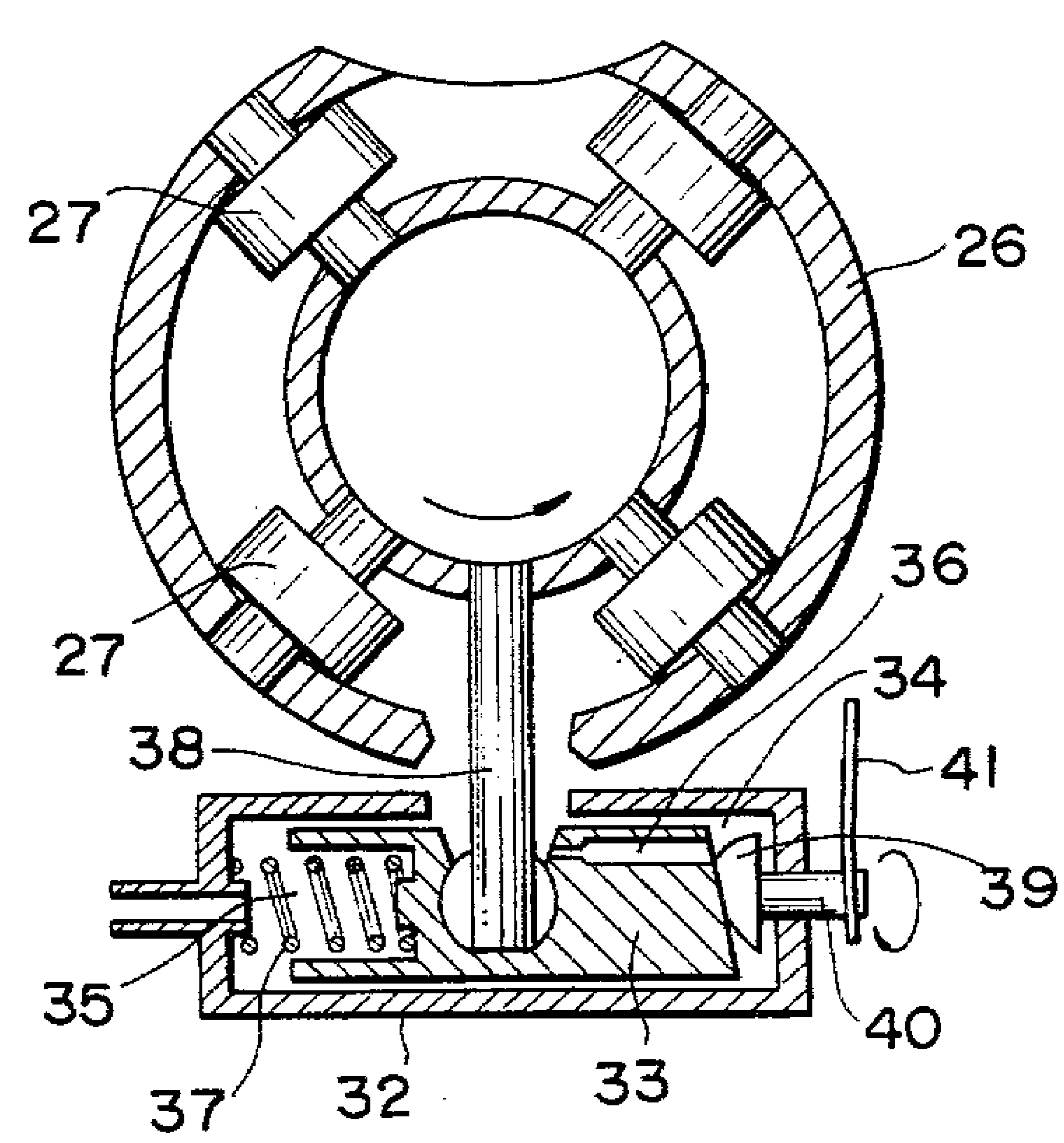
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FIG. 3

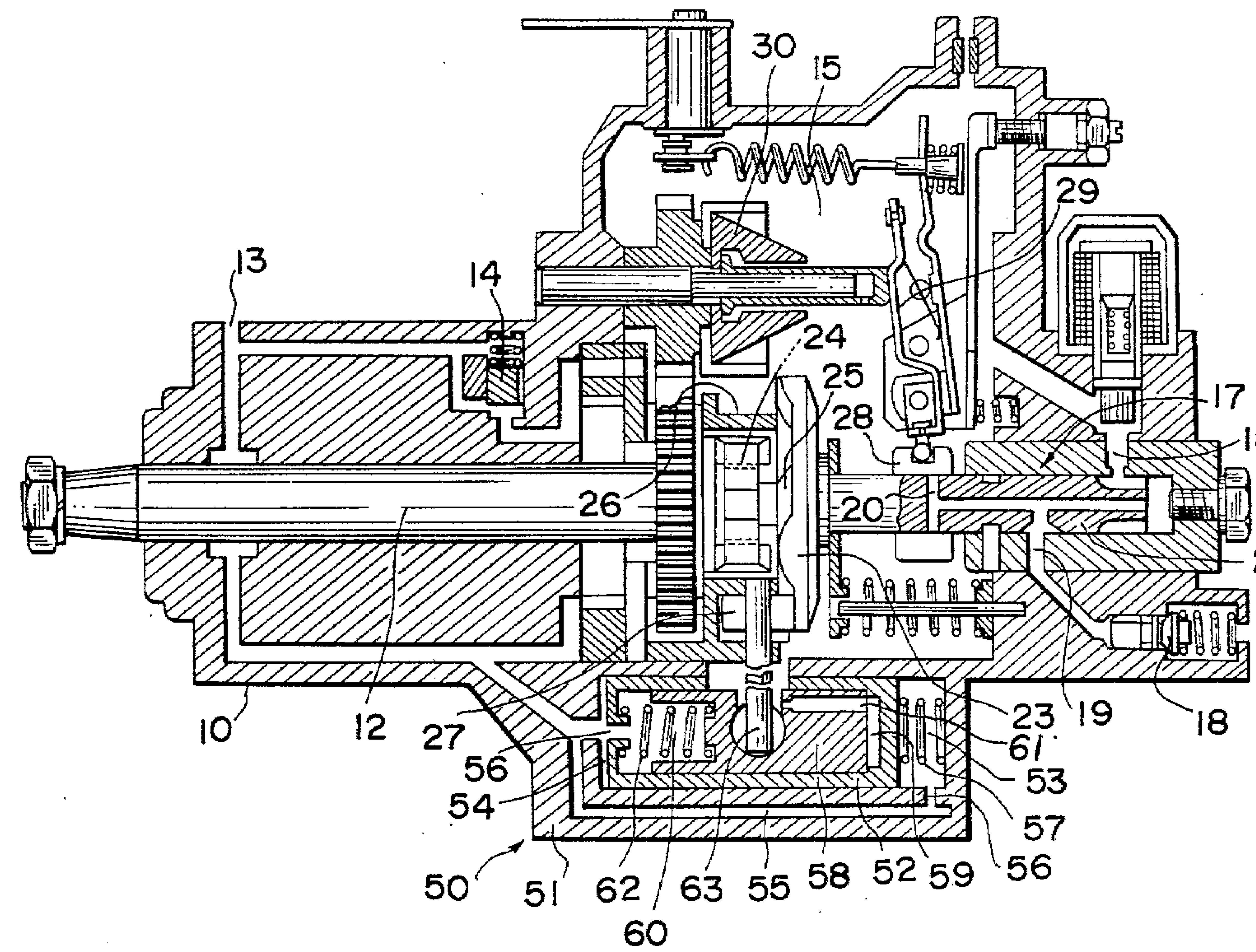
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FIG. 4

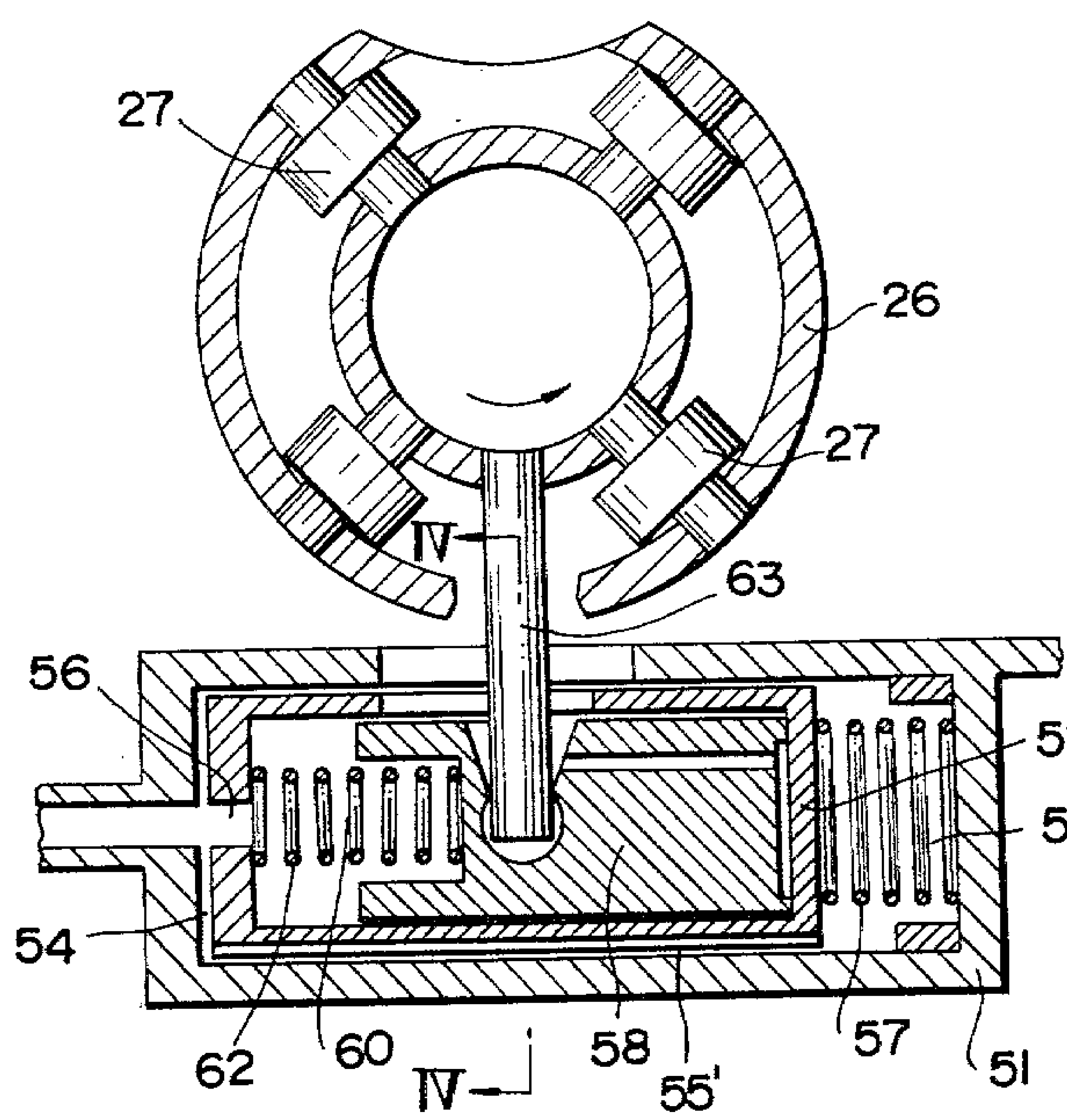


FIG. 5

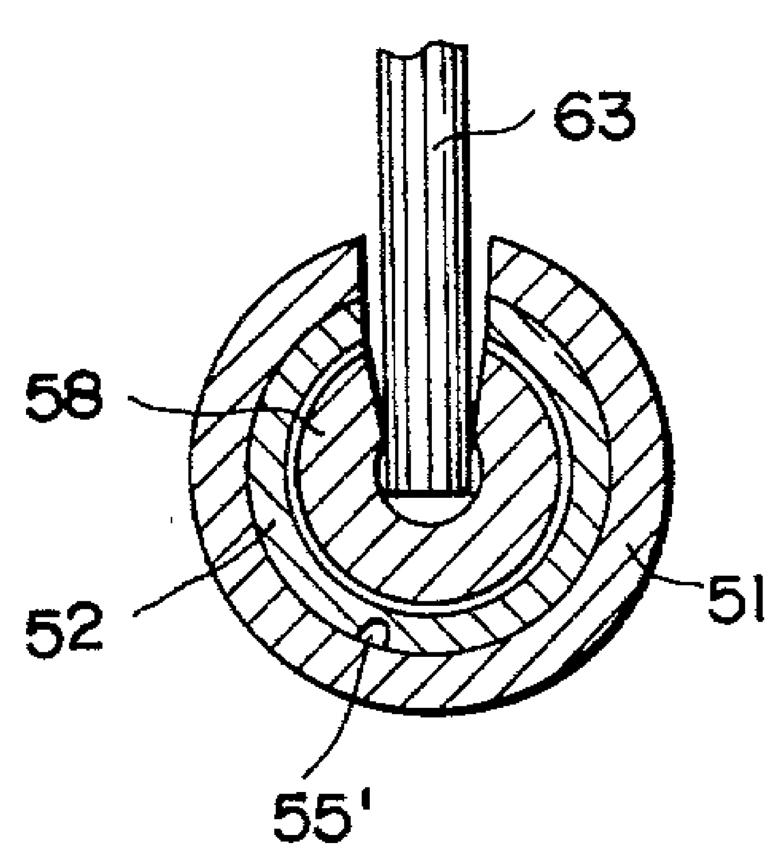


FIG. 6

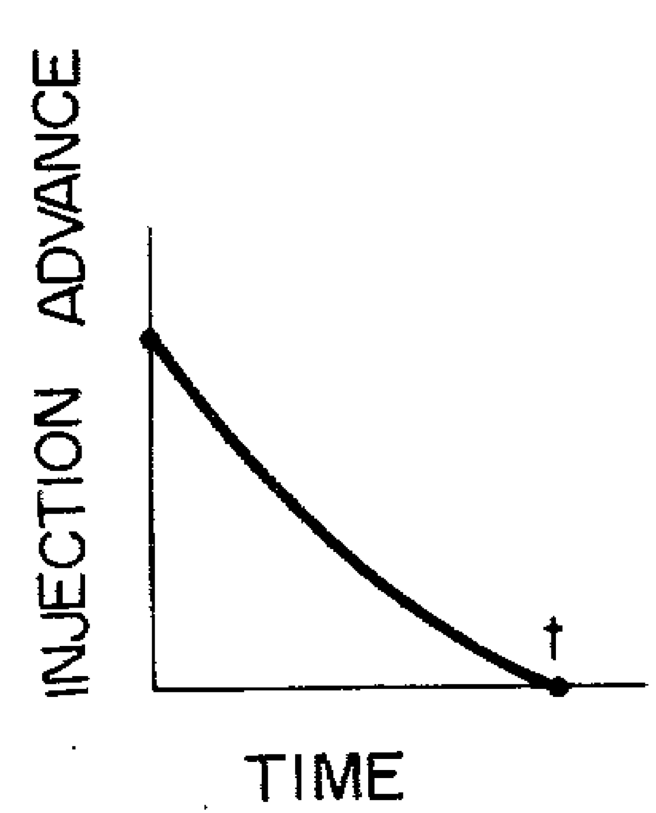


FIG. 7A

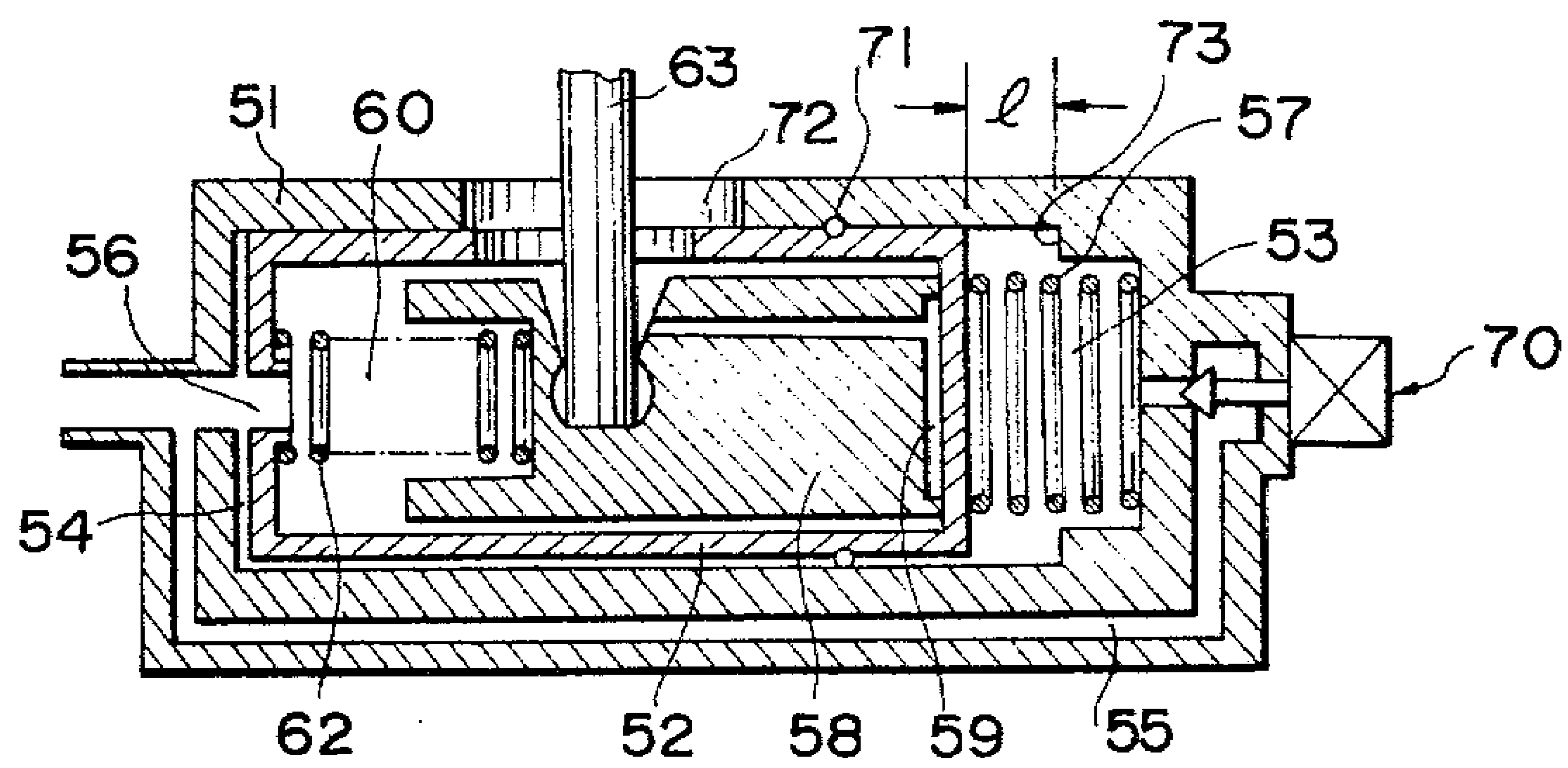


FIG. 7B

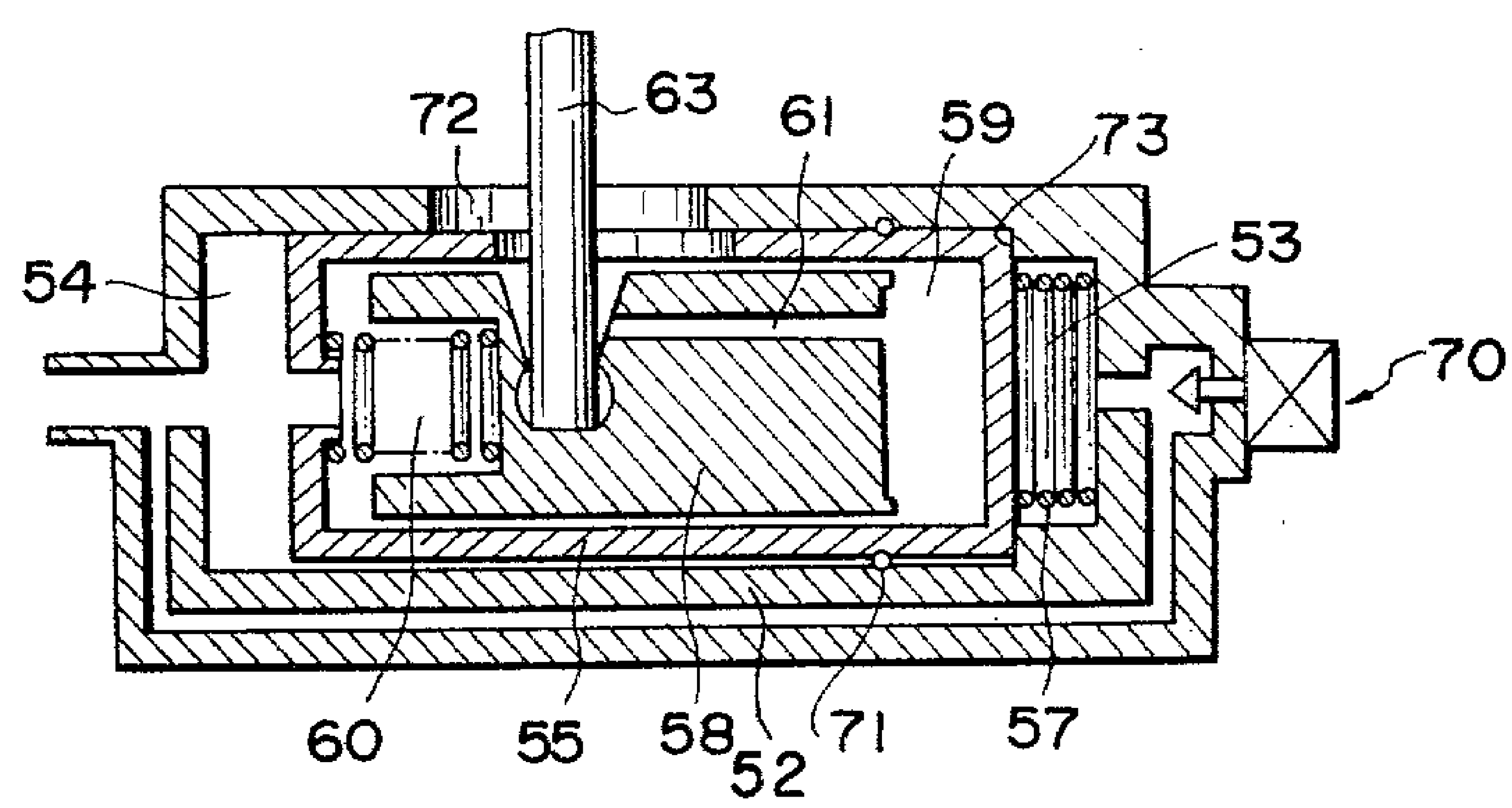


FIG. 8

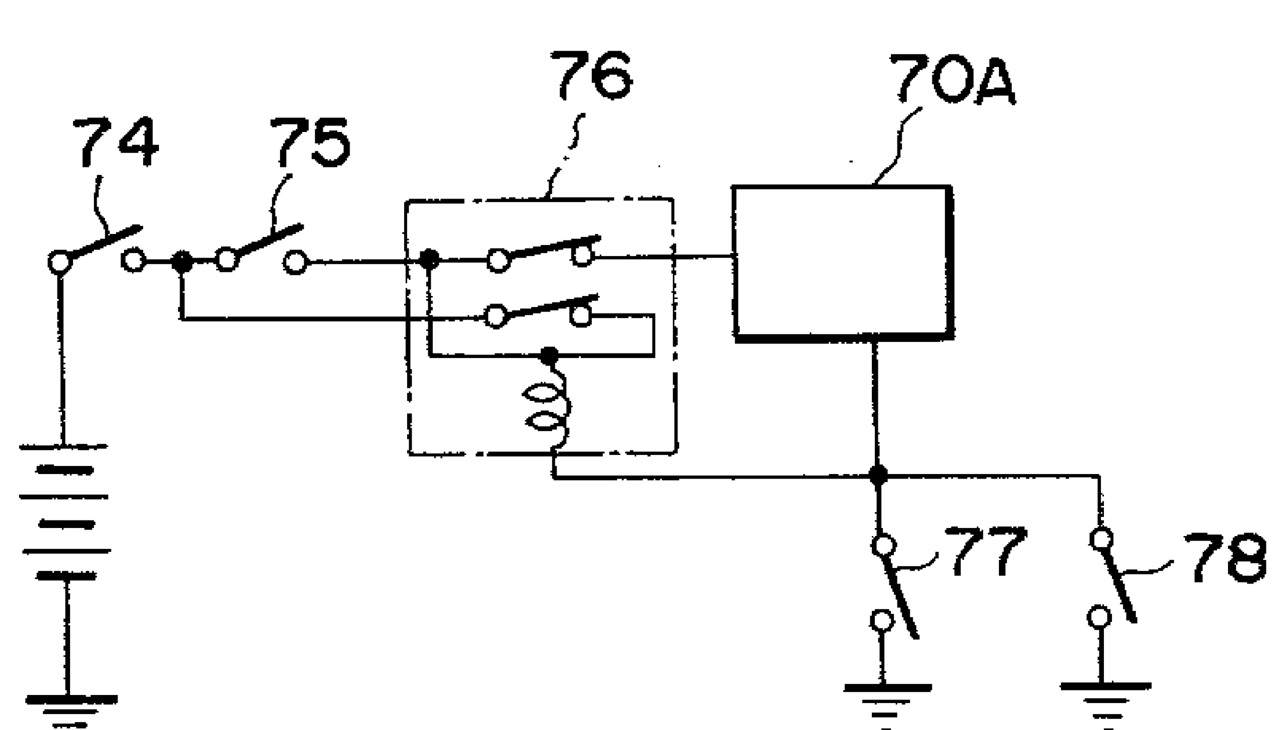


FIG. 9A

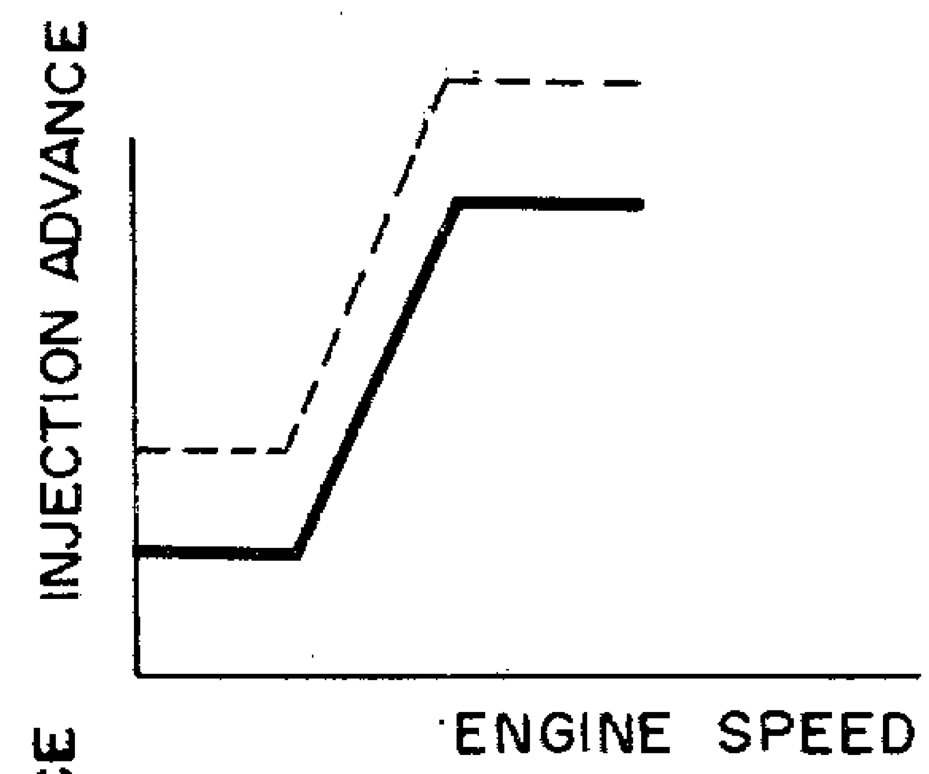


FIG. 9B

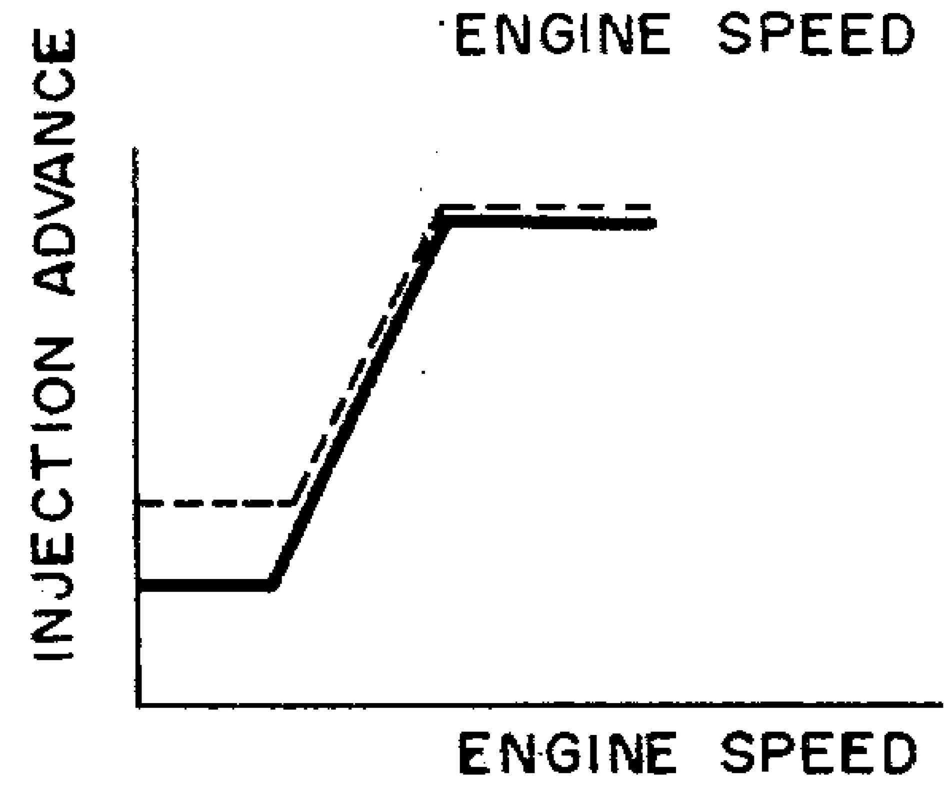


FIG. 10

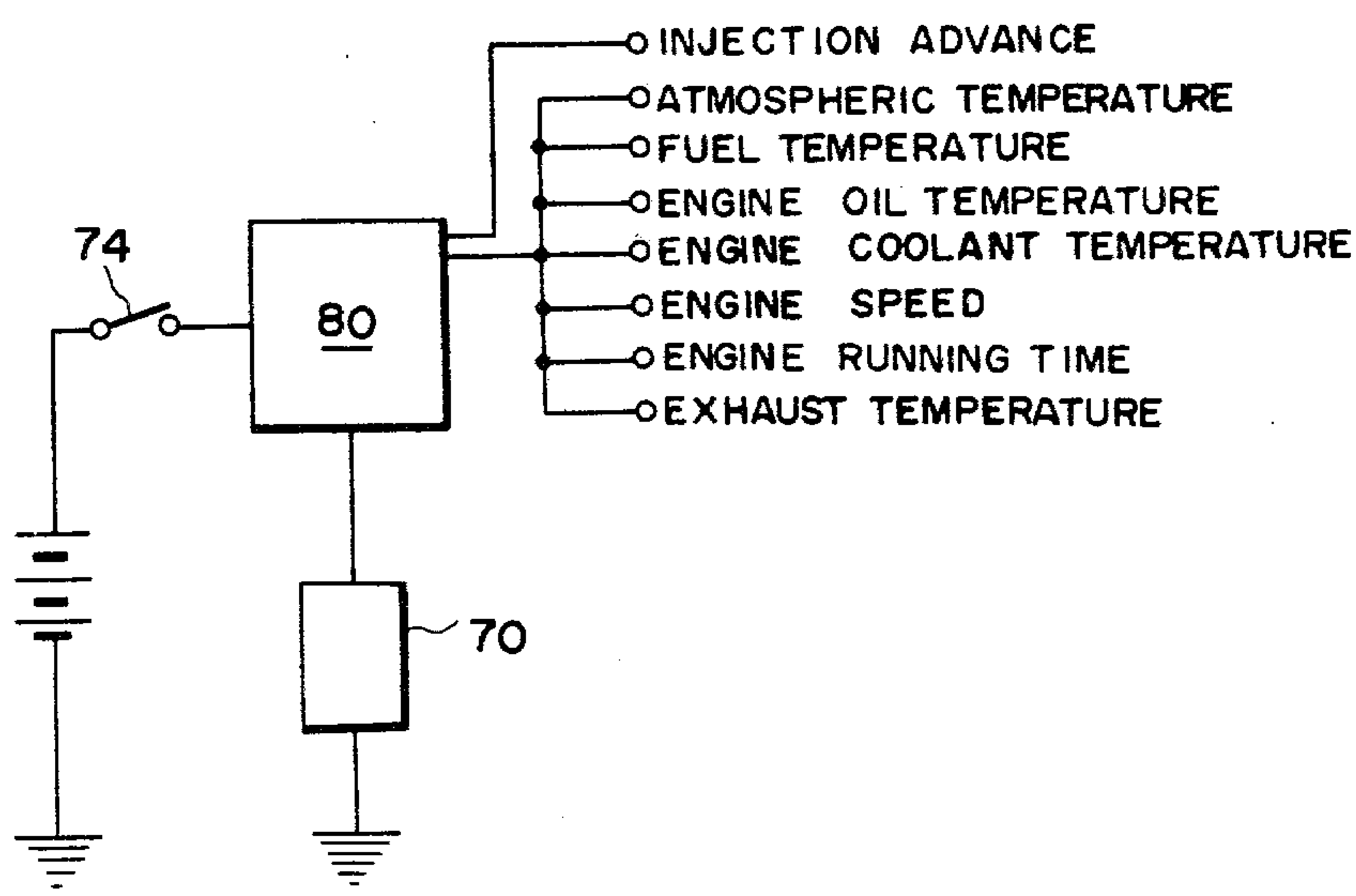


FIG. 11

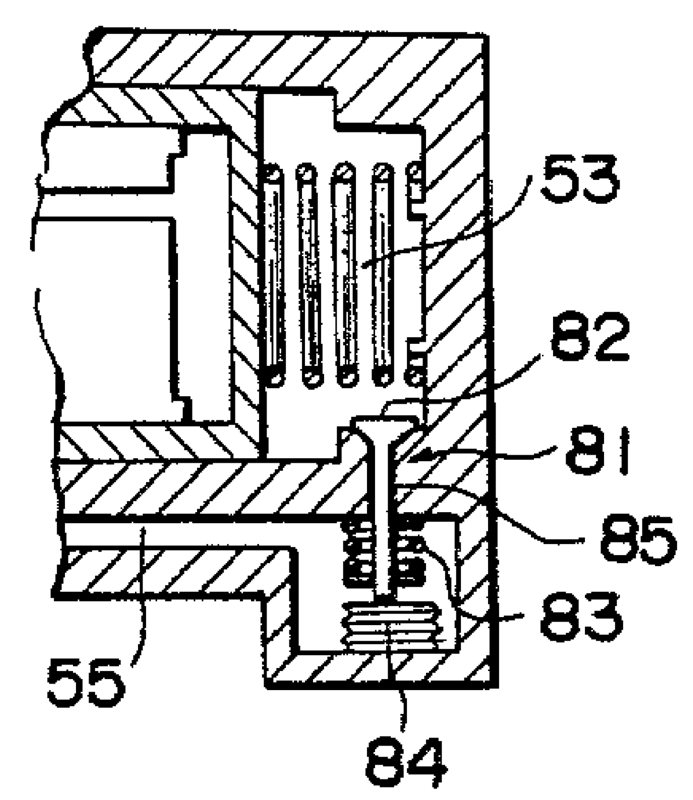


FIG. 12

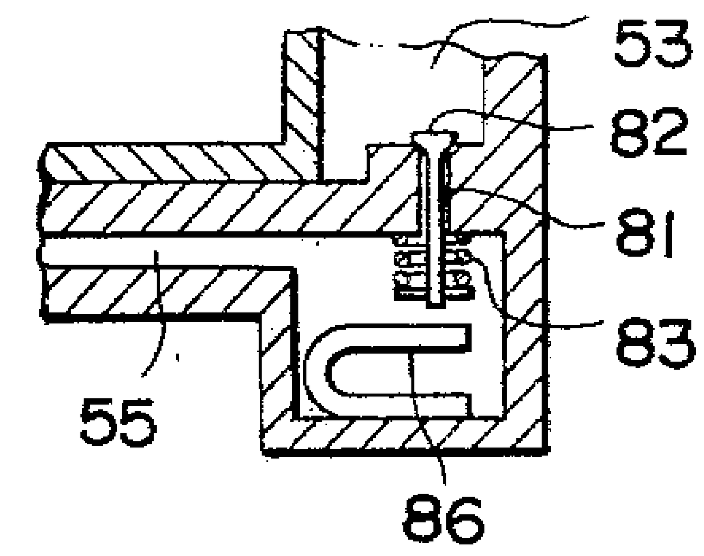


FIG. 13

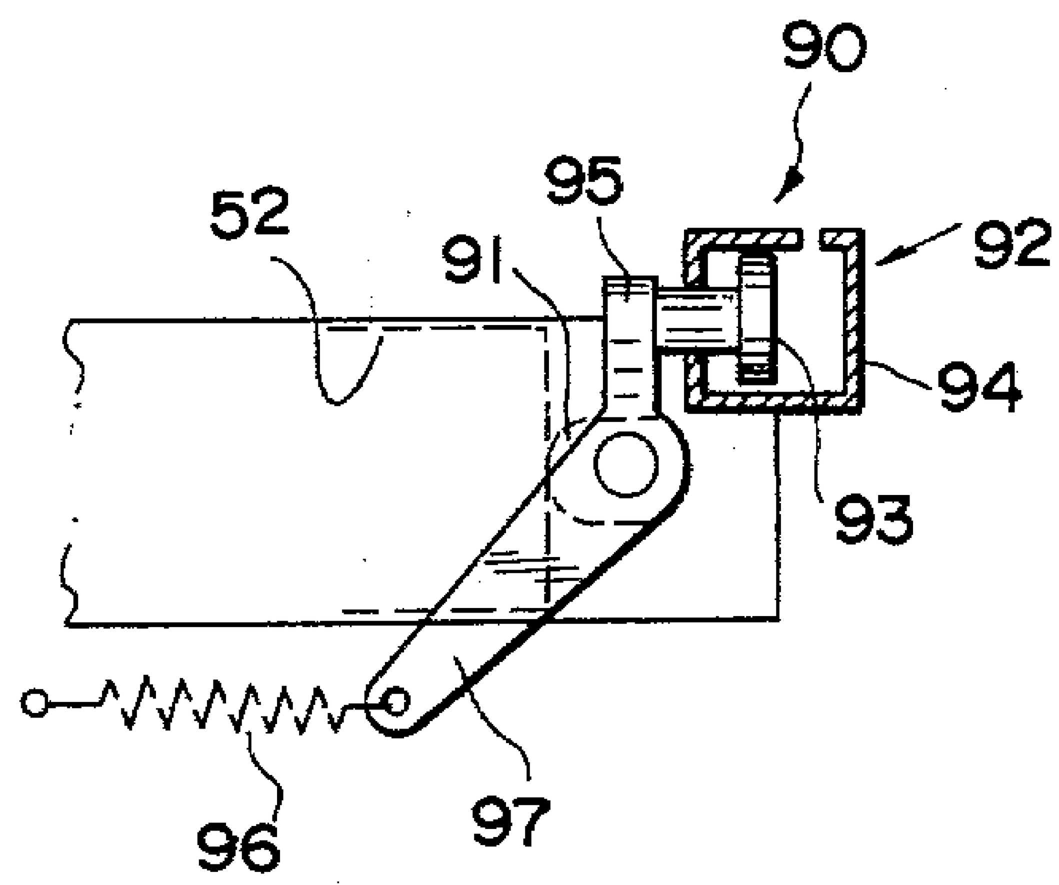


FIG. 14

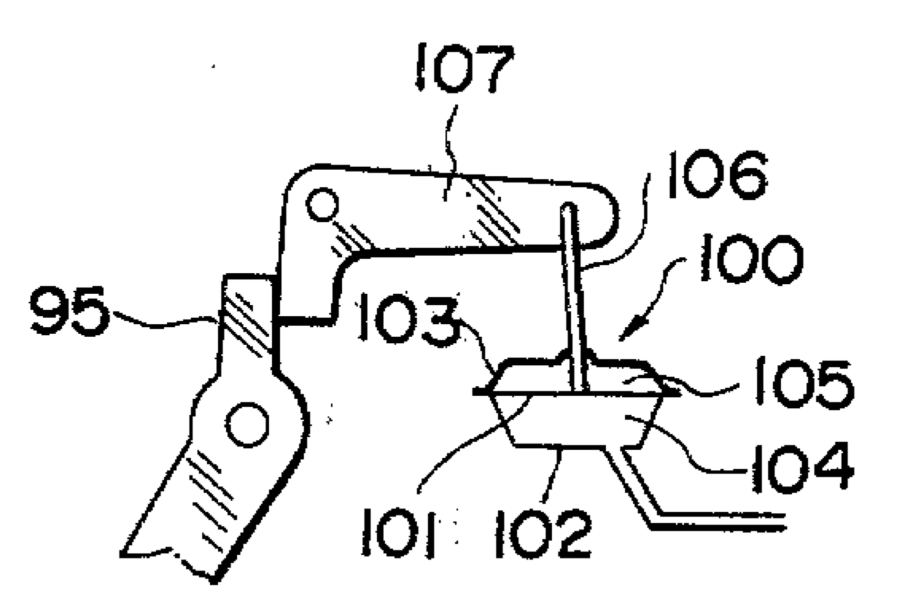


FIG. 15A

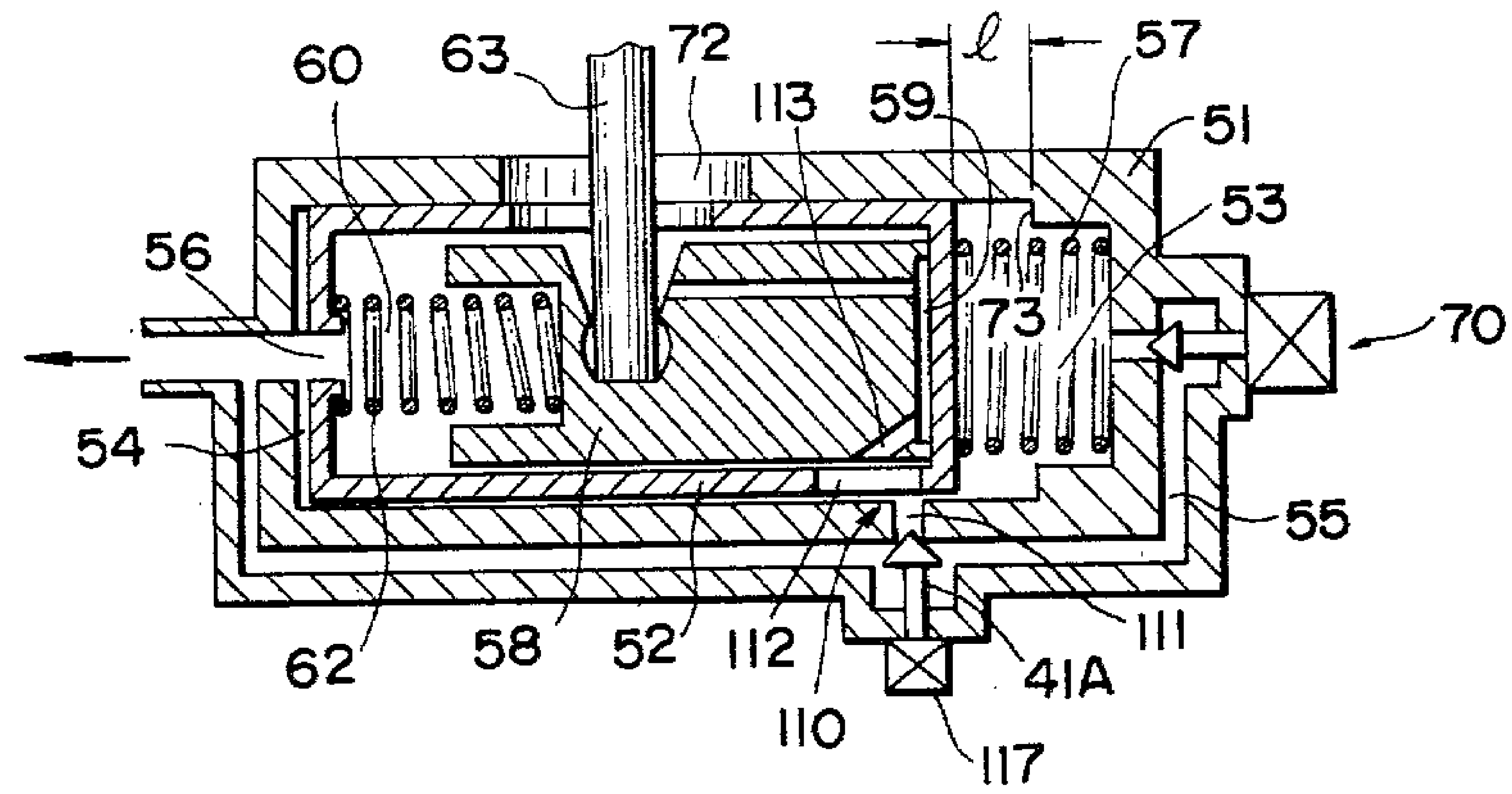


FIG. 15B

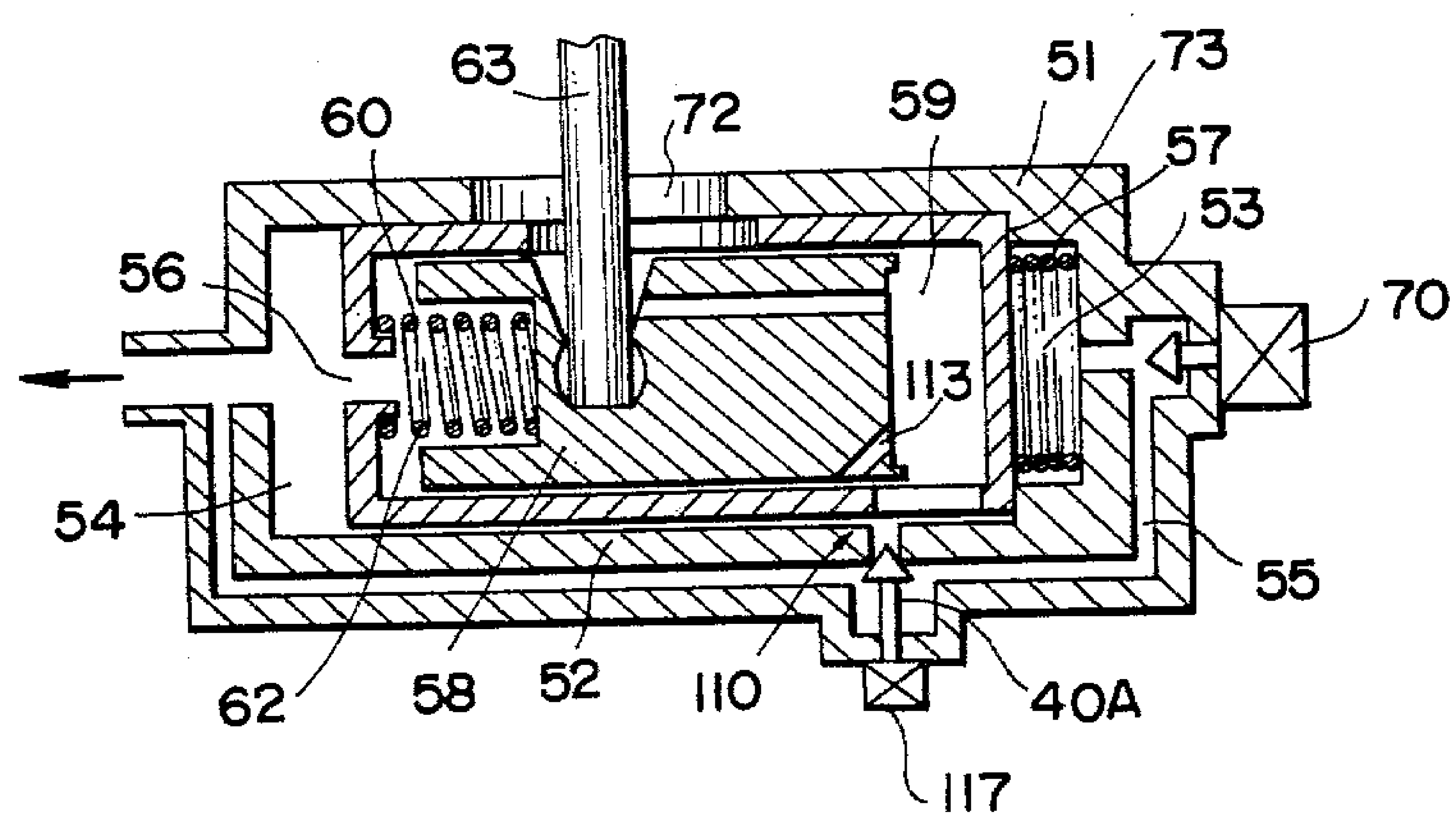


FIG. 16A

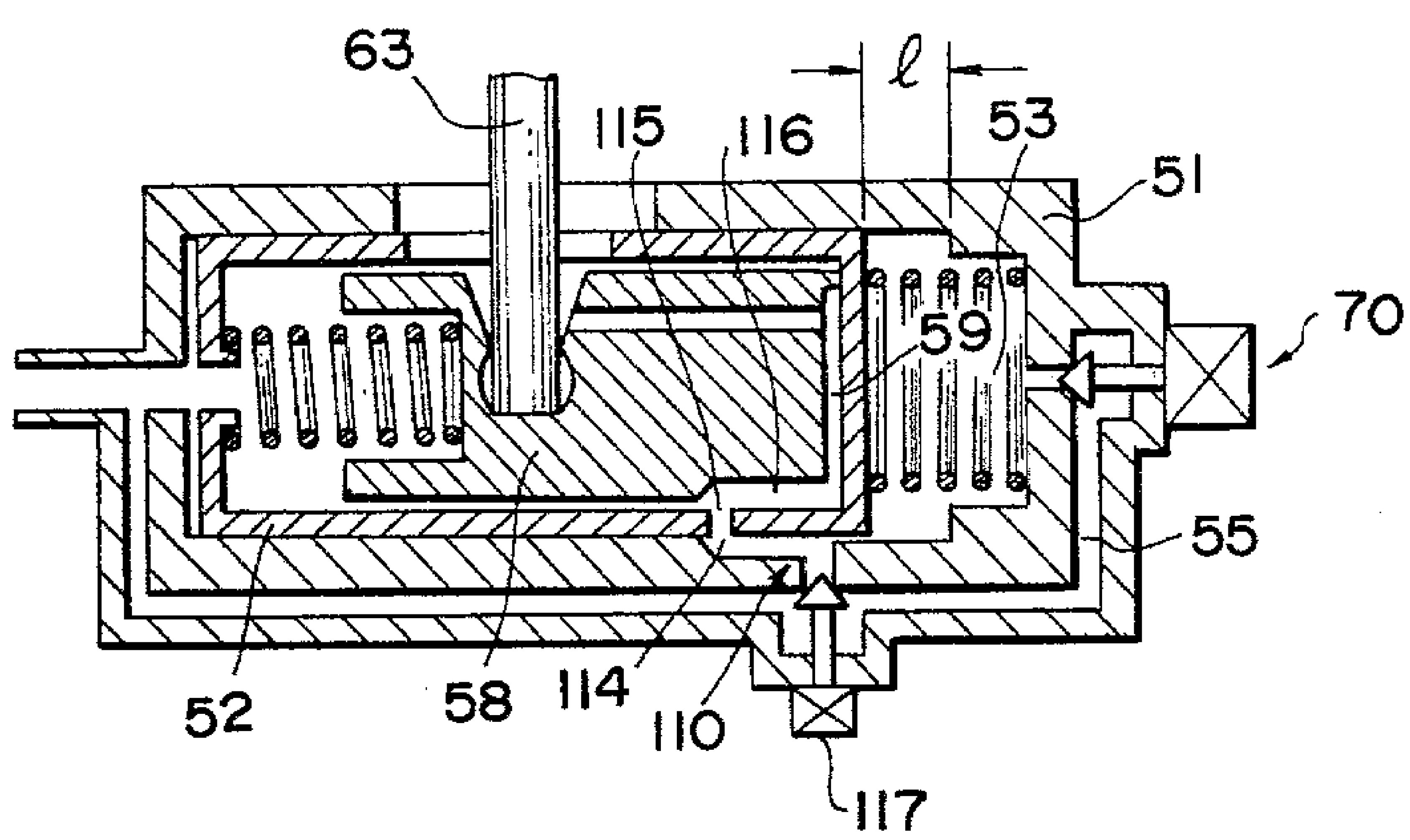


FIG. 16B

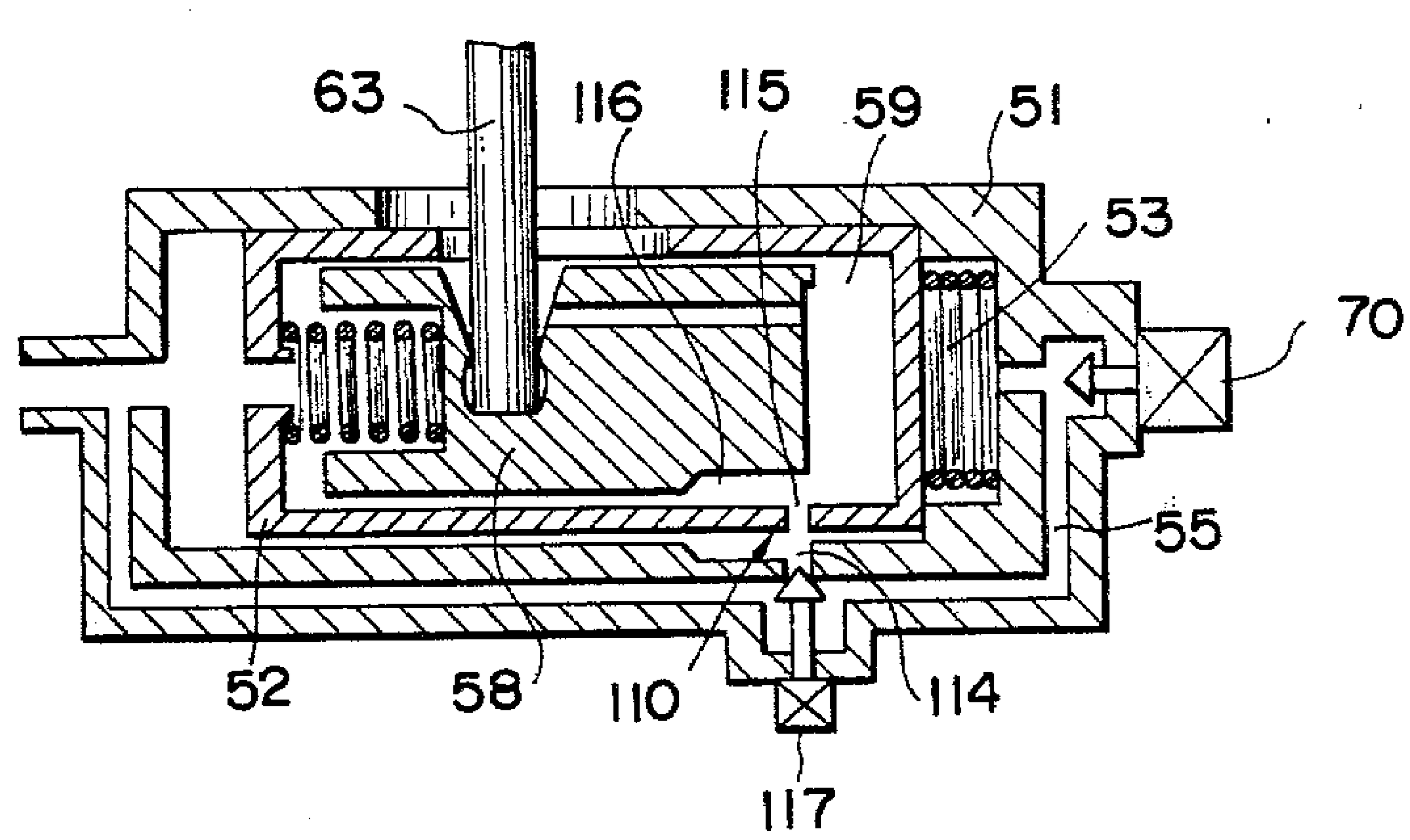


FIG. 17

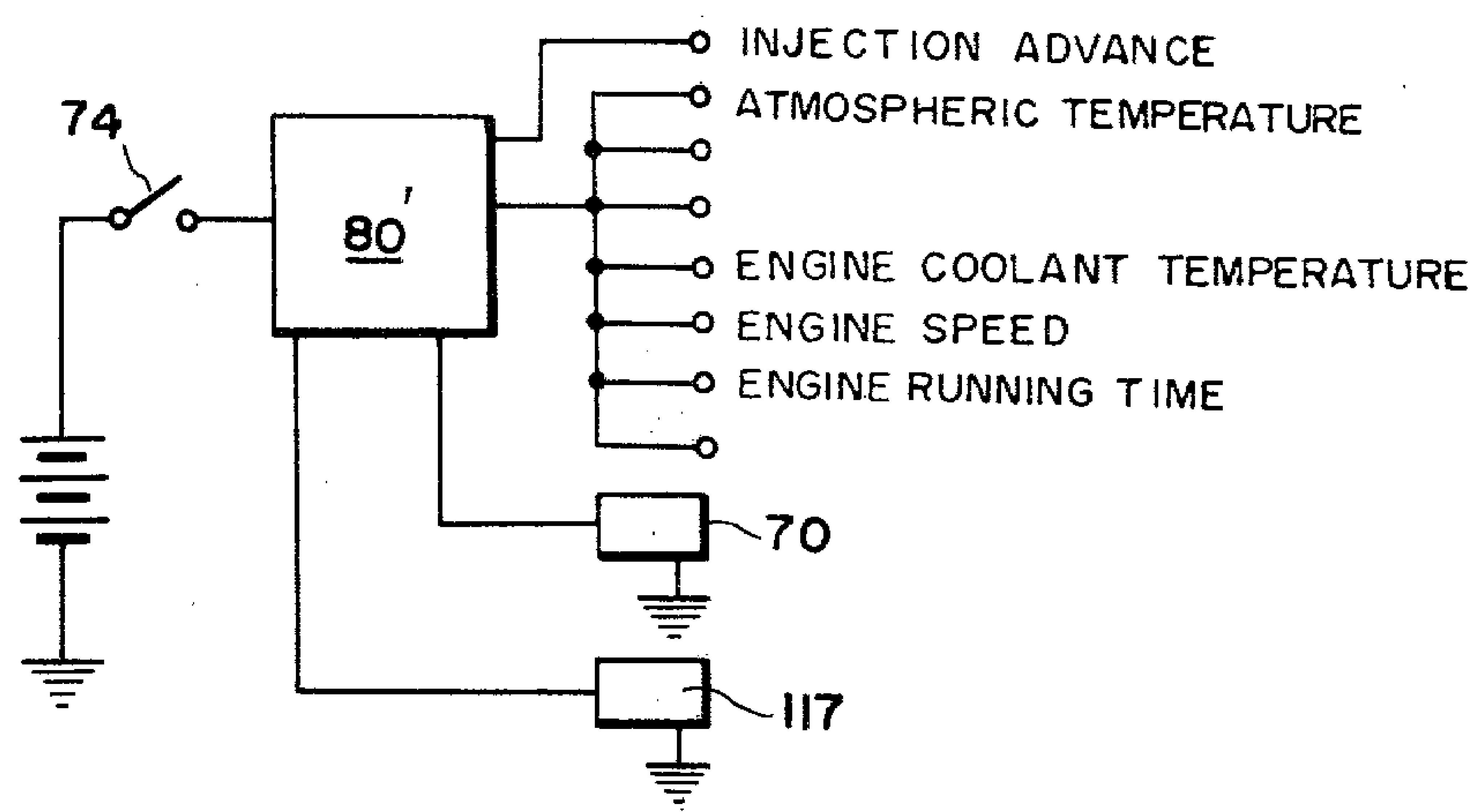

74
80'
INJECTION ADVANCE
ATMOSPHERIC TEMPERATURE
ENGINE COOLANT TEMPERATURE
ENGINE SPEED
ENGINE RUNNING TIME
70
117

FIG. 20

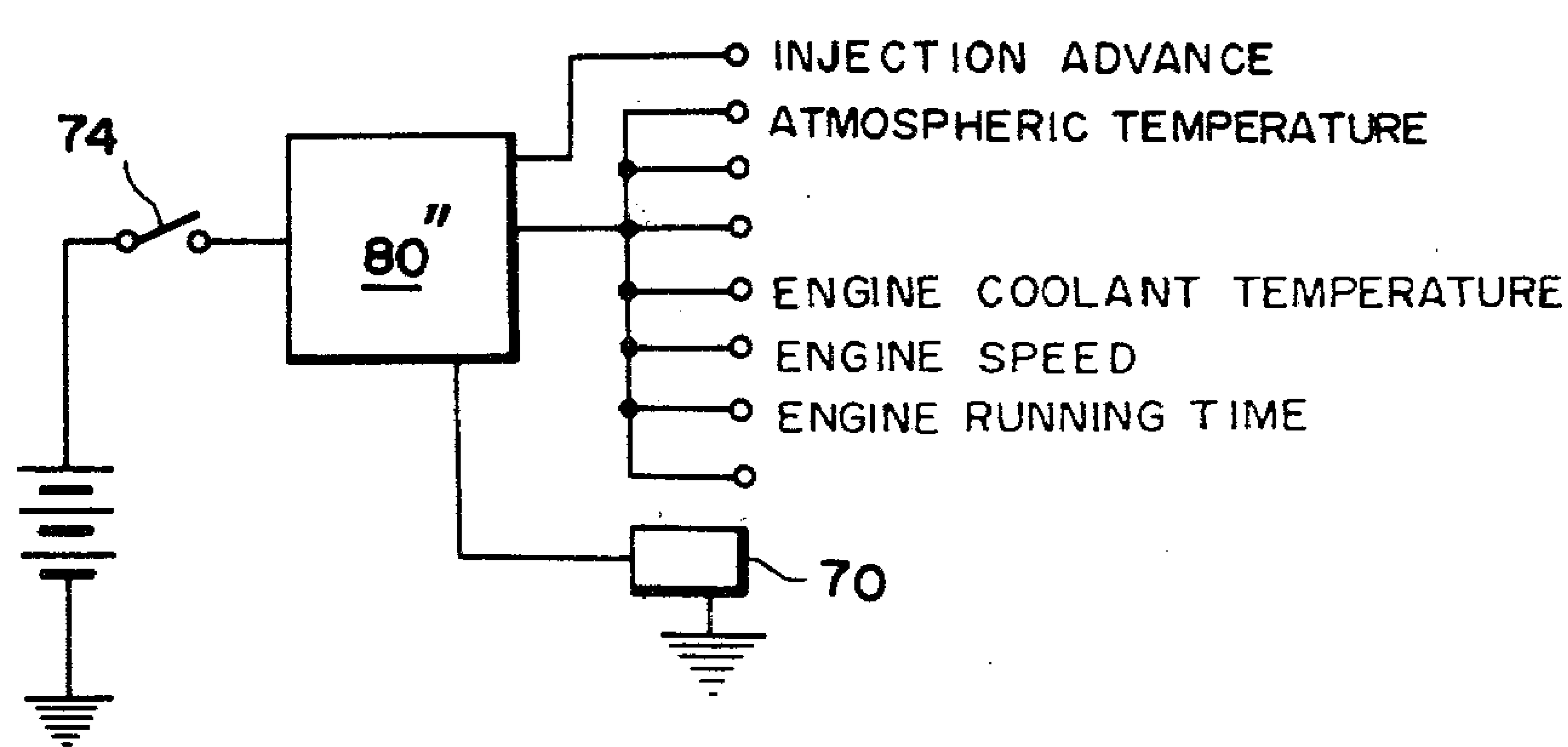

74
80"
INJECTION ADVANCE
ATMOSPHERIC TEMPERATURE
ENGINE COOLANT TEMPERATURE
ENGINE SPEED
ENGINE RUNNING TIME
70

FIG. 18

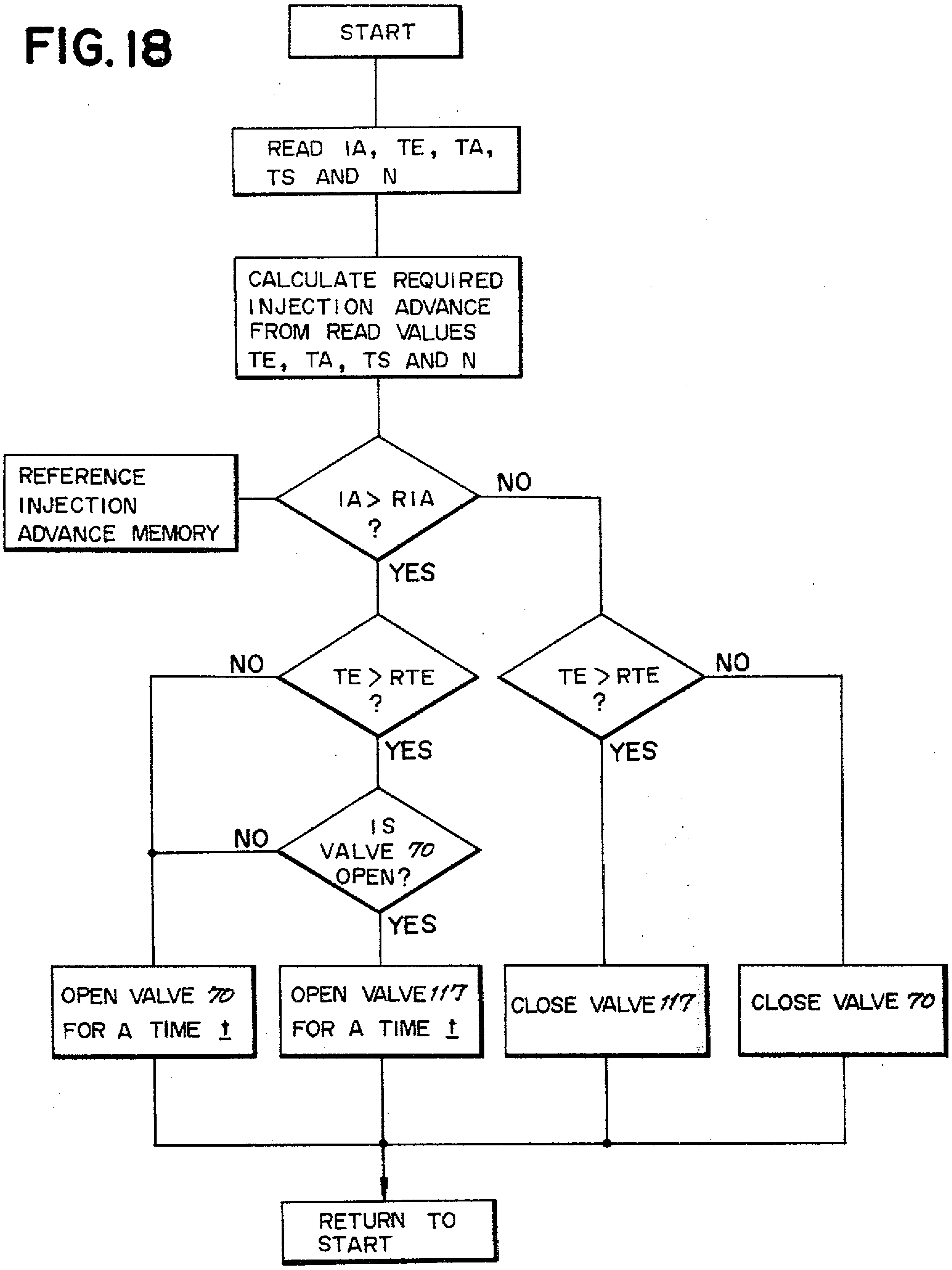

START
READ IA, TE, TA, TS AND N
CALCULATE REQUIRED INJECTION ADVANCE FROM READ VALUES TE, TA, TS AND N
REFERENCE INJECTION ADVANCE MEMORY
IA> RIA ?
NO
YES
TE > RTE ?
NO
YES
TE > RTE ?
NO
YES
IS VALVE 70 OPEN?
NO
YES
OPEN VALVE 70 FOR A TIME t
OPEN VALVE 117 FOR A TIME t
CLOSE VALVE 117
CLOSE VALVE 70
RETURN TO START

FIG. 19A

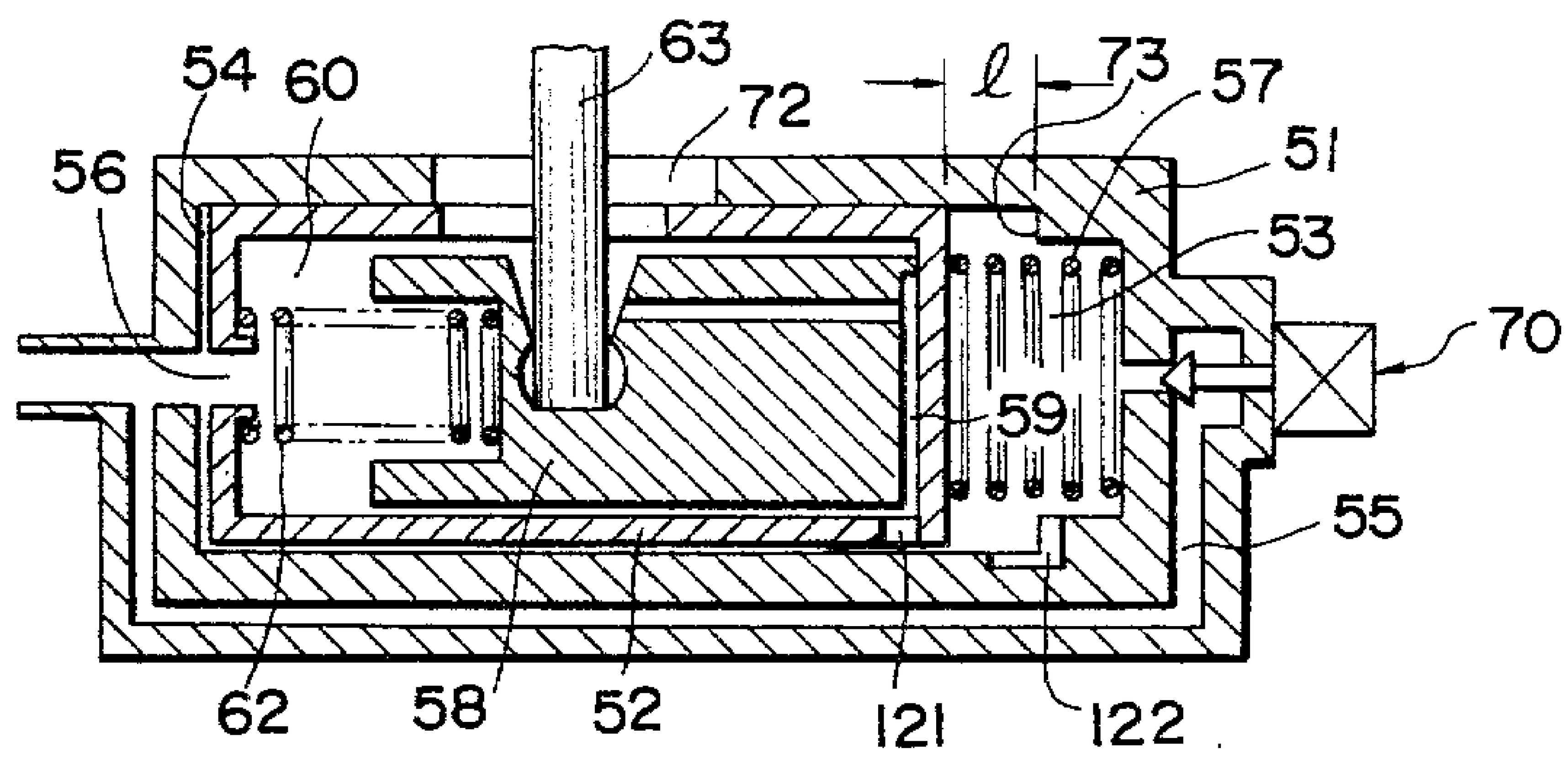


FIG. 19B

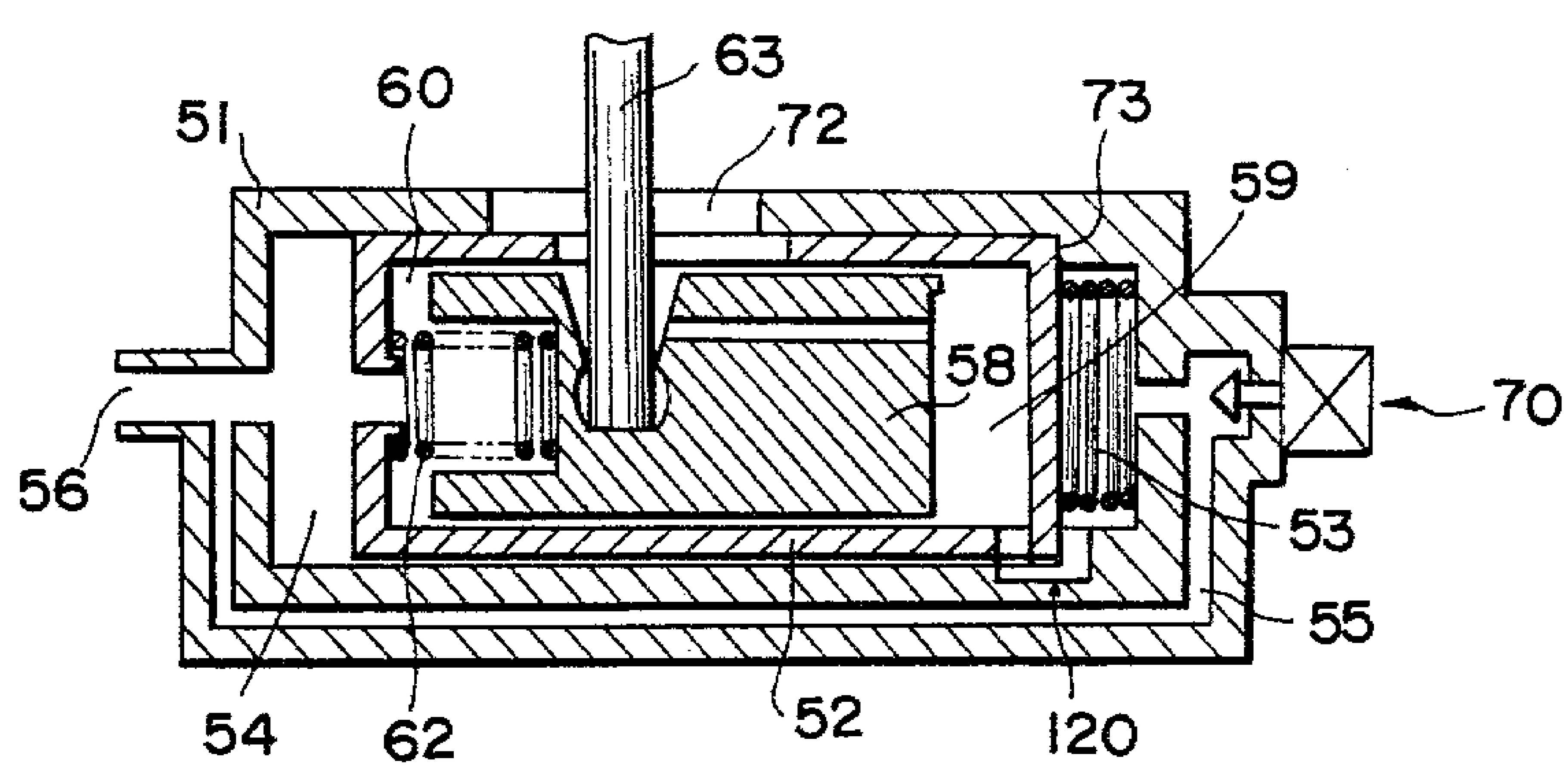


FIG. 21

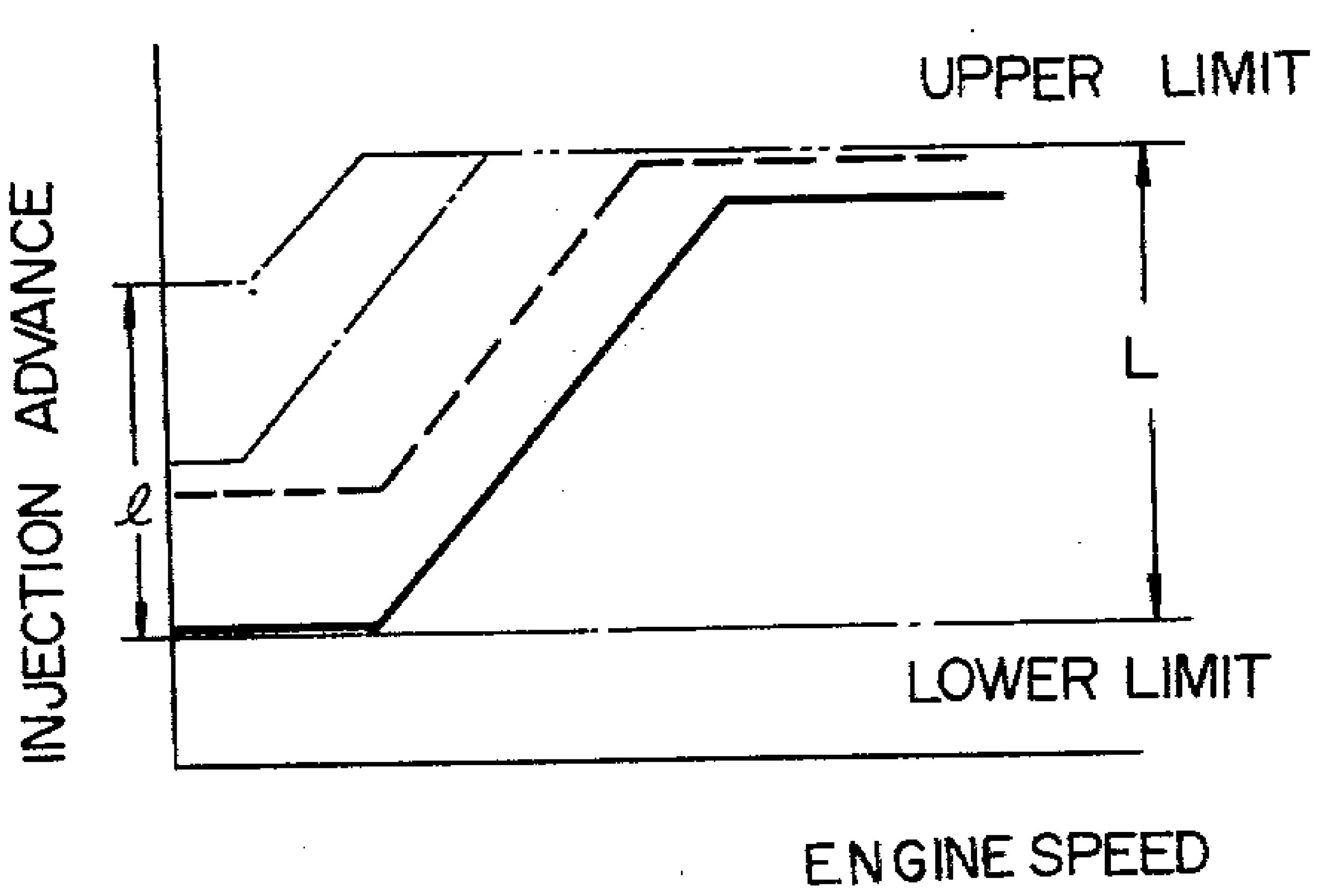


FIG. 22A

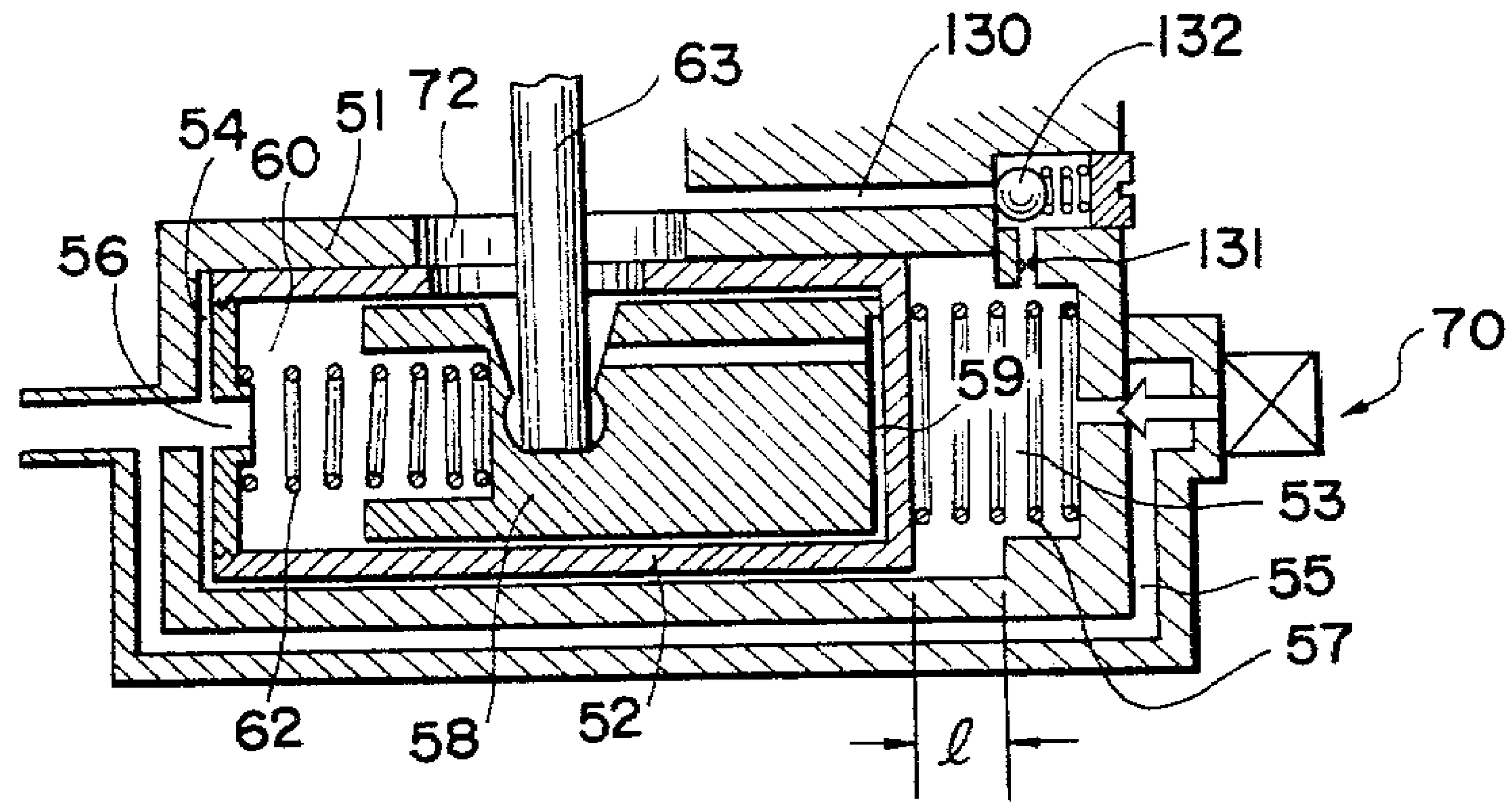


FIG. 22B

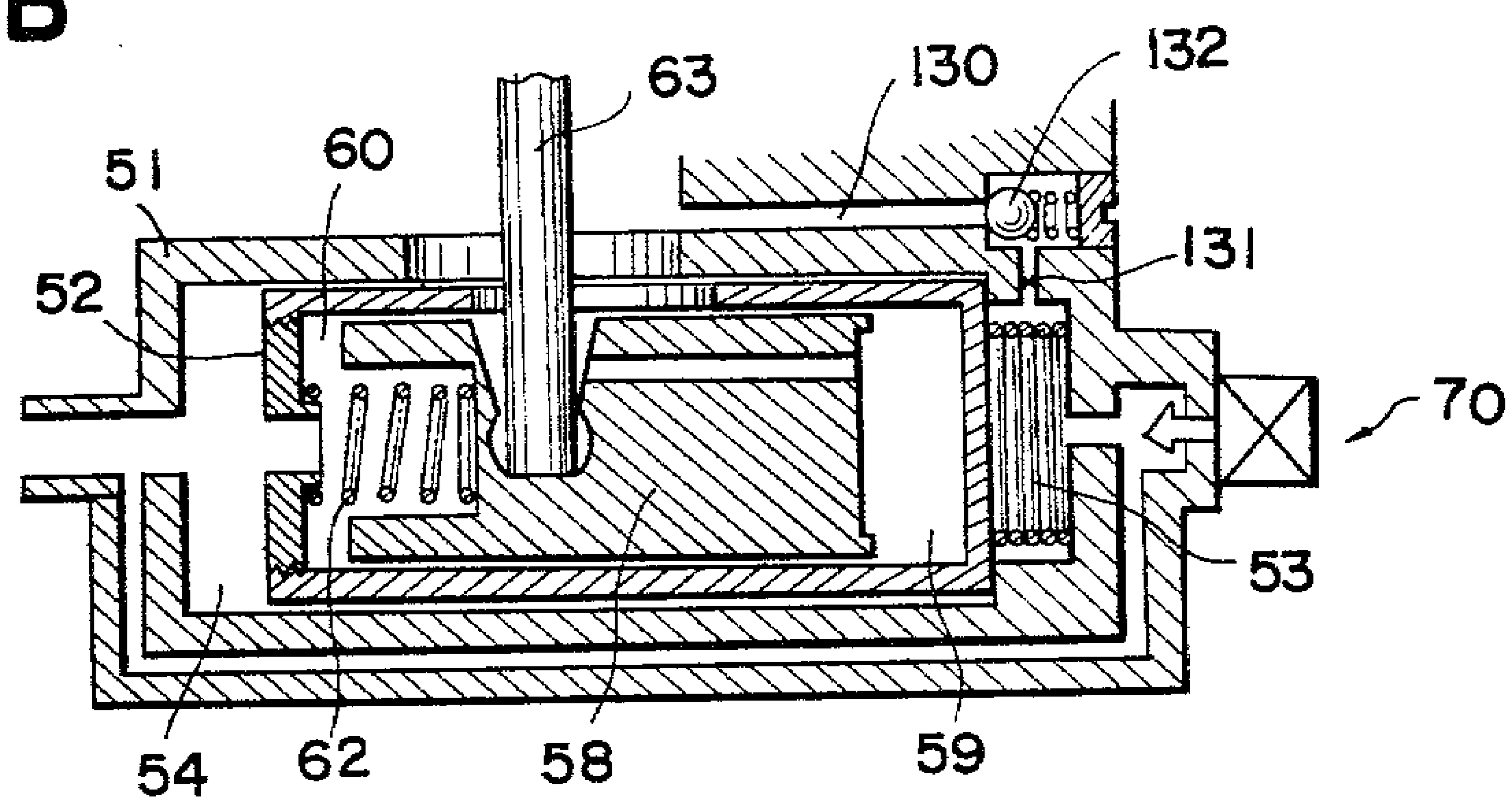


FIG. 23

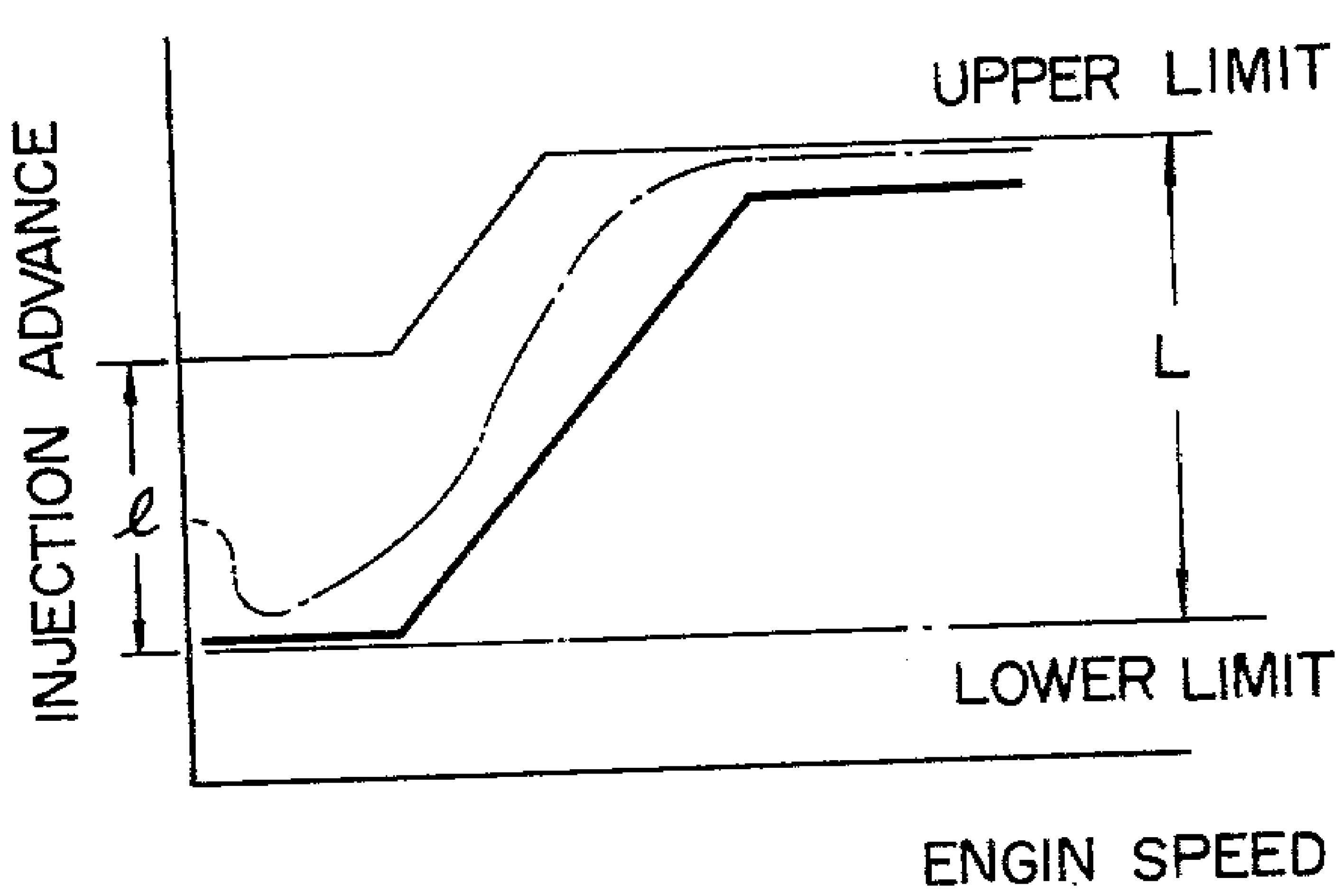
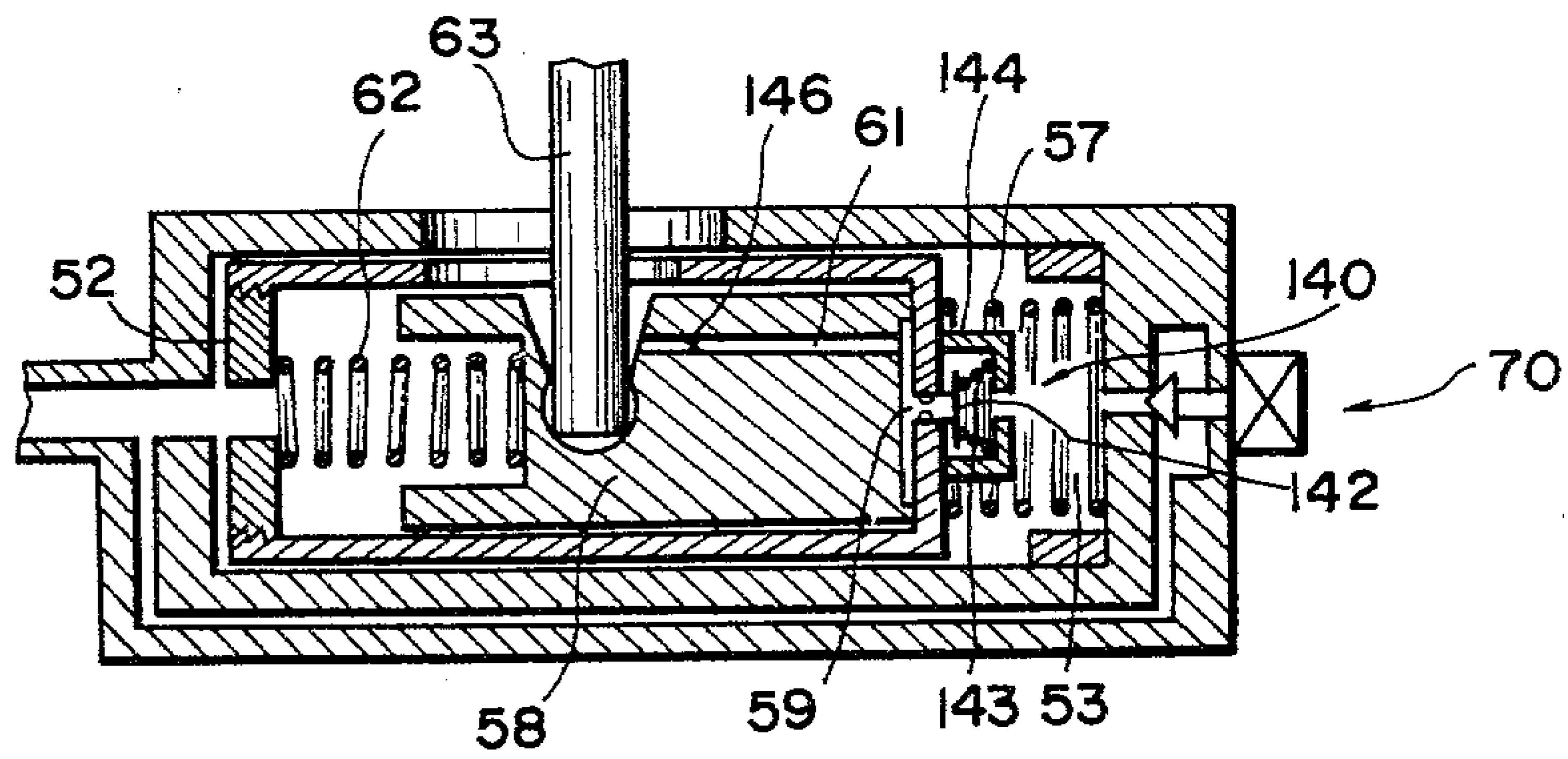


FIG. 24



INJECTION ADVANCE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a fuel injection pump for use in a diesel engine and, more particularly, to an automatic injection advance device for use therewith.

2. Description of the Prior Art

It is common practice in diesel engines to vary fuel injection timing in accordance with the frequency of rotation of the engine. For this purpose, diesel engines have a fuel injection pump with an injection advance device for injecting fuel with an advance determined by engine speed. In view of higher engine starting stability, such injection advance is important particularly when the engine is starting.

FIG. **1** is a longitudinal sectional view of a conventional fuel injection pump with the injection advance device being shown as rotated clockwisely 90 degrees from its actual position for convenience of illustration, and FIG. **2** is a transverse sectional view showing the relative relationship between the injection advance device and roller ring.

Referring to FIG. **1**, the fuel injection pump comprises a pump housing **10** containing therein a feed pump **11** driven by a drive shaft **12** drivingly connected with the engine (not shown). The feed pump **11** sucks fuel from an inlet **13** and discharges pressurized fuel through a pressure adjustment valve **14** into a pump chamber **15** formed in the pump housing **10**. The fuel charged into the pump chamber **15** is used to lubricate parts located within the pump chamber **15** and also is delivered to a piston valve **16**. The piston valve **16** includes a cylinder **17** fixed to the pump housing **10** and formed with an inlet port **18** opening into the pump chamber **15**, distributing ports **19** communicated with respective delivery valves **21**, and a spill port **20**. Provided for rotation and reciprocation within the cylinder **16** is a distributing piston **22** having therein a passage for selectively connecting two of the ports **18**, **19** and **20**. The distributing piston **22** is fixed to a cam disc **23** which in turn is connected through a suitable coupling **24** to the drive shaft **12**. The cam disc **23** is formed on its surface with face cams **25** numbered in accordance with the cylinders of the engine. A roller ring **26** is provided which fixedly supports rollers **27** for engagement with the face cams **25** of the cam disc **23**. As the drive shaft **12** rotates, the cam disc **23** rotates with its face cams **25** running over the rollers **27**, causing rotating and reciprocating movement of the distributing piston **22**. As a result, pressurized fuel is fed from the distributing ports **19** to the delivery valves **18** and hence to the fuel injection nozzles (not shown).

The amount of fuel injected through the fuel injection nozzles is determined by the position of a spill ring **28**. The spill ring **28** is mounted around a portion of the outer peripheral surface of the distributing piston **22** to cover the spill port **20** when the distributing piston **22** moves to the left in the drawing and open the spill port **20** to release pressurized fuel into the interior of the pump chamber **15** when it moves to the right in the drawing.

The position of the spill ring **28** is adjusted through a link lever **29** by a governor mechanism **30** which is drivingly connected to the drive shaft **12** so that the amount of fuel to the fuel injection nozzles is controlled

in accordance with the frequency of rotation of the engine.

The timing of fuel injection which occurs when the face cams **25** run on the rollers **27** is controlled by the angular position of the roller ring **26** with respect to the cam disc **23**. For example, if the roller ring **26** is rotated in a direction opposite to the direction of rotation of the cam disc **23**, then the face cams **25** ride on the rollers **27** at an earlier time so that fuel injection timing can be advanced with respect to engine crank angle. For this purpose, an injection advance device **31** is provided to adjust the angular position of the roller ring **26** in accordance with the frequency of rotation of the engine.

Referring to FIG. **2**, the injection advance device **31** includes a cylinder **32** and a piston **33** reciprocally located in the bore of the cylinder **32** to divide the cylinder bore into two chambers **34** and **35** at the respective ends of the piston **33**. The chamber **34** is communicated through a passage **36** with the pump chamber **15**. The chamber **35** is connected to the inlet side of the feed pump **11** and held at a low pressure. A spring **37** is provided within the chamber **35** to urge the piston **33** to the right in the drawing. The piston **33** is formed with a recess which receives one end of a drive pin **38** extending through the pump chamber **15** to the roller ring **26**.

The fuel pressure in the pump chamber **15** increases in proportion to increase in the frequency of rotation of the feed pump and thus the engine, causing leftward movement of the piston **33** to rotate the roller ring **26** in a direction opposite to the direction of rotation of the cam disc **23** indicated by the arrow so that fuel injection is advanced in accordance with engine speed.

In addition, the injection advance device is associated with manual injection advance means for improving fuel combustion during engine starting. The manual injection advance means includes a cam **39** having a slant face in contact with the piston **33**. The cam **39** is rotated through a rotary shaft **40** by a hand-operated lever **41** to force leftward movement of the piston **33** so that fuel can be injected with an advance corresponding to a predetermined crank angle.

In such a conventional injection advance device where injection advance necessary during engine starting is made by manual rotation of the lever **1**, however, complex engine starting operations are required which often leads to a failure to operate the manual injection advance means, resulting in unstable engine starting. Furthermore, a large actuator is required to automatically move the piston **33** against a strong force of the spring **37** when the engine is starting.

SUMMARY OF THE INVENTION

It is therefore one object of the present invention to provide an injection advance device which can automatically hold fuel-injection timing advanced before the engine is warmed up.

Another object of the present invention is to provide an injection advance device which can automatically provide an optimum fuel-injection timing according to engine warming conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description of the present invention is had in conjunction with the accompanying drawings, in which like reference characters refer to the same or corresponding parts, and wherein:

FIGS. **1** and **2** are sectional views showing a convenshown in FIG. **15A**. When the engine is started, the cam

FIG. 3 is a sectional view showing one embodiment of an injection advance device made in accordance with the present invention;

FIGS. 4 and 5 are sectional views showing a modified form of the injection advance device, wherein FIG. 5 is a sectional view taken along line V—V of FIG. 4;

FIG. 6 is a graph showing variations in injection advance provided by the device of the invention;

FIGS. 7A and 7B are sectional views showing a second embodiment of the present invention;

FIG. 8 is a circuit diagram showing a valve drive circuit used in the device of FIGS. 7A and 7B;

FIG. 9A is a graph showing injection advance characteristics provided by the device of the invention;

FIG. 9B is a graph showing injection advance characteristics provided by a conventional device;

FIG. 10 is a circuit diagram showing another form of the valve drive circuit;

FIGS. 11 and 12 are sectional views showing modifications of the device of FIGS. 7A and 7B;

FIGS. 13 and 14 are schematic views showing modifications of the device of FIGS. 7A and 7B;

FIGS. 15A and 15B are sectional views showing a third embodiment of the present invention;

FIGS. 16A and 16B are sectional views showing a modified form of the device of FIGS. 15A and 15B;

FIG. 17 is a circuit diagram showing a valve drive circuit used in the device of the third embodiment;

FIG. 18 is a flow chart used to explain the operation of the valve drive circuit of FIG. 17;

FIGS. 19A and 19B are sectional views showing a fourth embodiment of the present invention;

FIG. 20 is a circuit diagram showing a valve drive circuit used in the fourth embodiment;

FIG. 21 is a graph showing injection advance characteristics provided by the present invention;

FIGS. 22A and 22B are sectional views showing a fifth embodiment of the present invention;

FIG. 23 is a graph showing injection advance characteristics provided by the present invention; and

FIG. 24 is a sectional view showing a modified form of the device of FIGS. 22A and 22B.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 3, a fuel injection pump, embodying the present invention, is shown with the injections advance device being shown as rotated clockwisely 90 degrees from its actual positions. The structure shown in FIG. 3 is generally the same as shown in FIGS. 1 and 2 except for the injection advance arrangement, and like reference numerals in FIG. 3 indicate like parts as described with reference to FIGS. 1 and 2.

The fuel injection pump includes an automatic injection advance device 50 made in accordance with the present invention. The automatic injection advance device 50 comprises a casing 51 forming integrally with the pump housing 10, and a cylinder 52 reciprocally located in the bore of the casing 51, dividing the casing bore into two chambers 53 and 54 at the respective ends of the cylinder 52. The chamber 54 is connected to the inlet side of the feed pump 11 and the chamber 53 is connected to the inlet side of the feed pump 11 through a release passage 55 having therein an orifice 56. In this embodiment, the release passage 55 is shown as being formed in the casing 51. The cylinder 52 is closed at its one end and formed at the other end thereof with an opening 56. A spring 57 is provided within the chamber 53 to urge the cylinder 52 to the left in the drawing.

A piston 58 is reciptocally located in the bore of the cylinder 52 to divide the cylinder bore into two chambers 59 and 60 at the respective ends of the piston 58. The chamber 59 is communicated through a passage 61 with the pump chamber 15 and the chamber 60 is connected through the opening 56 to the inlet side of the feed pump 11. A spring 62 is provided within the chamber 60 to urge the piston 58 to the right in the drawing. The piston 58 is formed with a recess which receives one end of a drive pin 63 extending through the cylinder 52 and the casing 51 to the roller ring 26.

During normal engine operation, the fuel pressure in the chamber 59 increases with increase in engine rotational frequency, causing leftward movement of the piston 58 against the force of the spring 62 so as to rotate the roller ring 26 in a direction opposite to the direction of rotation of the cam disc 23, whereby fuel injection is advanced in accordance with engine rotational frequency.

When the engine is off, the piston 58 is held at the position, as shown in FIG. 3, by the force of the spring 57 so that fuel can be injected with an advance predetermined suitably for engine starting. Although the cam disc 23 rotates and exerts forces on the roller ring 26 such as to move the cylinder 52 to the right through the drive pin 63 after the engine is started, the orifice 56 provided in the release passage 55 restricts the flow of fuel discharged to the inlet side of the feed pump 11 and increases the fuel pressure in the chamber 53 so as to provide a resistance against the rightward movement of the cylinder 52. As a result, the fuel injection timing is held advanced for a time after the engine is started. The time required for the cylinder 52 to move to its rightmost position is dependent upon the viscosity of the fuel. That is, the lower the engine temperature, the lower is the speed at which the cylinder 52 moves to the right.

Referring to FIGS. 4 and 5, a modified form of the automatic injection advance device 50 is shown wherein the release passage 55 formed in the casing 51 is eliminated and instead the cylinder 52 is formed in its outer peripheral surface with an axial groove having a predetermined length and cross-sectional area to define a release passage 55′ with the inner surface of the casing 51 for communication of the chamber 53 with the chamber 54 and hence with the inlet side of the feed pump 11. The release passage 55′ restricts the flow of fuel discharged from the chamber 53 and increases the fuel pressure in the chamber 53 so as to provide a resistance against the rightward movement of the piston 58 after the engine is started. As a result, the fuel injection timing is held advanced for a time after the engine is started.

FIG. 6 shows variations in injection advance with time wherein the character t indicates the time required for the injection advance falls to zero. The time t is dependent upon engine speed, fuel temperature, and other engine conditions and is proportional to a value l/a wherein l is the length of the groove and a is the cross-sectional area of the groove. Accordingly, a desired time t can be selected by the choice of the length and cross-sectional area of the groove. The groove may be formed in spiral form in the outer peripheral surface of the cylinder 52. Thus, the length l of the groove can be freely selected although the cross-sectional area a is selected a limited range from the machining accuracy standpoint. It is to be noted, of course, that the groove may be formed in the inner surface of the casing **51** to define the release passage **55'** with the outer periperal surface of the cylinder **52**.

Referring to FIGS. 7A and 7B, there is illustrated a second embodiment of the present invention which is substantially similar to the structure previously described in connection with FIG. **4** except that a solenoid valve **70** is provided in the release passage **55**. The solenoid valve **70** is closed to block the flow of fuel from the chamber **53** for a predetermined time after the engine is started. In FIGS. 7A and 7B, the reference numeral **71** designates a seal ring and the numeral **72** an elongated hole formed in the casing **51** for free movement of the drive pin **63**.

When the engine is off, the cam disc **23** remains still and exerts no force on the roller ring **26**, whereas the fuel pressure in the chamber **59** is equal to that in the chamber **60**. Thus, the piston **58** is moved to the right with respect to the cylinder **52** under the force of the spring **62** and the cylinder **52** is moved to the left with respect to the casing **51** under the force of the spring **57** so that the drive pin **63** is held in its neutral position as shown in FIG. 7A. When the engine is started, the cam disc **23** rotates and exerts forces on the roller ring **26** such as to move the piston **58** to the right through the drive pin **63**. At this time, however, the solenoid valve **70** remains closed closing the release passage **55** to prevent rightward movement of the cylinder **52** so as to provide an injection advance corresponding to the length l as shown in FIG. 7A which is predetermined for engine starting.

When the engine is warmed up and the solenoid valve **70** opens to provide communication between the chamber **53** and the inlet side of the feed pump **11**, the fuel pressure conducted from the pump chamber **15** into the chamber **59** pushes the piston **58** to the left against the force of the spring **60** and the resulting reaction force moves the cylinder **52** rightward against the force of the spring **57** until the cylinder **52** abuts against the shoulder **73** of the casing **51** as shown in FIG. 7B. Thereafter, the fuel pressure in the chamber **59** increases in proportion to increase in engine rotational frequency, causing leftward movement of the piston **58** to rotate the roller ring **26** in a direction opposite to the direction of rotation of the cam disc **23** so that fuel injection is advanced in accordance with engine speed.

Referring to FIG. **8**, there is illustrated a circuit for driving the solenoid valve **70**. The circuit includes an engine key switch **74**, a starter switch **75**, a self-hold type relay **76**, a pressure responsive switch **77** adapted to become off when the fuel pressure is above a predetermined time; that is, when the engine speed is above a predetermined value, and a temperature responsive switch **78** adapted to become off when the engine coolant temperature is above a predetermined value.

When the key switch **74** and the starter switch **75** are turned on to start the engine, both of the pressure and temperature responsive switches **77** and **78** are on so that the valve solenoid **74A** is energized to close the valve **70**. The self-hold type relay **76** holds the temperature responsive switches **77** and **78** are turned off even if the starter switch **75** is turned off. Thus, if the vehicle starts running before the engine is not fully warmed up, the injection advance is always higher than that obtained when the vehicle starts running after the engine is fully warmed up. This is shown in FIG. 9A wherein the broken curve indicates variations in injection advance when the vehicle starts running before the engine is not fully warmed up and the solid curve indicates variations in injection advance when the vehicle starts running after the engine is fully warmed up. With conventional injection advance devices, the injection advance is held higher than that obtained when the vehicle starts running after the engine is fully warmed up only in an initial period after the vehicle starts running as shown in FIG. 9B wherein the broken curve indicates variations in injection advance when the vehicle starts running before the engine is not fully warmed up and the solid curve indicates variations in injection advance when the vehicle starts running after the engine is fully warmed up.

FIG. **10** shows another form of the solenoid valve drive circuit wherein a micro-computer **80** is utilized to provide a pulse signal with its duty cycle varied in accordance with various engine warming conditions such as atmospheric temperature, fuel temperature, engine oil temperature, engine coolant temperature, engine speed, exhaust temperature and engine running time to the valve solenoid so as to alternatively open and close the solenoid valve **70** to thereby allow a gradual reduction in injection advance.

FIG. **11** shows a modified form of the injection advance device wherein the solenoid valve **70** is eliminated and instead a temperature responsive valve **81** is provided in the release passage **55**. The temperature responsive valve **81** comprises a poppet valve **82** fitted in an opening **85** through which the chamber **53** is connected to the release passage **55**, a return spring **83** urging the poppet valve **82** to its closed position, and a thermostat element **84** placed at a position facing the poppet valve **82**. The thermostat element **84** expands at increased fuel temperatures to push the poppet valve **82** against the force of the return spring **83** so as to open the temperature responsive valve **81**. The thermostat element **84** may be removed and replaced with a bimetal element **86** as shown in FIG. **12**. The bimetal element **86** expands at increased fuel temperatures to push the poppet valve **82** against the force of the return spring **83** so as to open the temperature responsive valve **81**.

FIG. **13** shows another modification of the injection advance device wherein the cylinder **52** is moved by a mechanism **90** including a cam **91** held in contact with the right-hand end of the cylinder **52**, a hydraulic cylinder **92** having a piston **93** reciprocally located within its cylinder chamber **94**, a lever **95** drivingly connecting the piston **93** to the cam **91**, a spring **96** rotating the cam **91** in a clockwise direction through a lever **97**. After the engine is warmed up, pressurized fuel is charged into the cylinder chamber **94** to push the piston **94**, causing couter-clockwise rotation of the lever **95** to allow rightward movement of the cylinder **52** so as to reduce the injection advance to zero. When the engine is started, the lever **95** is rotated in the clockwise direction to provide an injection advance by the force of the spring **96**. As shown in FIG. **14**, the hydraulic cylinder **92** may be removed and replaced with a servo mechanism **100** which includes a diaphragm **101** mounted between the housing **102** and cover **103** to form therewith two chambers **104** and **105** on opposite sides of the diaphragm **101**. A drive rod **106** is provided which has its one end fixed centrally on the diaphragm **101** and the other end connected to a L-shaped lever **107** for driving the lever **95**. After the engine is warmed up, vacuum is introduced into the chamber **104** to cause counter-clockwise rotation of the lever **95** so as to reduce the injection advance to zero.

Referring to FIGS. **15A** and **15B**, there is illustrated a third embodiment of the present invention which is generally similar to the structure previously described in connection with FIGS. 7A and 7B except that a second release passage **110** is formed for communication of the chamber **59** with the first release passage **55** regardless of the position of the cylinder **52**. The second release passage **110** includes an opening **111** formed in the casing **51**, a slit **112** formed in the cylinder **52**, and a slant passage **113** formed in the piston **58** for ensuring communication between the chamber **59** and the slit **112** at the rightmost position of the cylinder **52**. The second release passage **110** has therein a second solenoid valve **117** adapted to open, according to need, so as to allow the flow of fuel from the chamber **59** through the second release passage **110** to the first release passage **55** and hence to the inlet side of the feed pump **11**.

It is to be noted, of course, that the second release passage **110** may be made up of a slit **114** formed in the casing **51**, an opening **115** formed in the cylinder **52**, and a groove **116** formed in the piston **58** as shown in FIGS. **16A** and **16B**. In addition, the groove **116** may be formed in the cylinder **52**.

FIG. **17** illustrates a circuit **80'** for controlling the operation of the first and second solenoid valves **70** and **117** wherein the numeral **74** designates an engine key switch. The valve control circuit **80'** receives various signal indicative of atmospheric temperature, engine temperature, engine speed, engine running time, and other engind operating conditions, and also an injection advance indicative signal from an injection advance detector (not shown) adapted to monitor the injection advance from the displacement of the injection nozzle needle valves and the fuel pressure through the injection passages for closing and opening the first and second solenoid valves **70** and **117** so that an optimum injection advance can be obtained in accordance with engine operating conditions.

FIG. **18** is a flow chart showing the operation of the control circuit **80'** of FIG. **17**. The control circuit **80'** reads engine temperature TE, intake air temperature TA, engine speed N, engine running time TS and fuel-injection advance IA, and calculates the required injection advance from the read values TE, TA, N and TS. Following this, a determination is made as to whether or not the calculated value IA is higher than a reference value RIA stored in a memory. If the calculated value IA is lower than the reference value RIA, the control circuit **80'** closes the second solenoid valve **117** under a condition where the engine temperature TE is higher than a reference value RTE, whereas it closes the first solenoid valve **70** until the engine is warmed up under a condition where the engine temperature TE is lower than the reference value RTE.

If the calculated value IA is higher than the reference value RIA, another determination is made as to whether or not the engine temperature TE is higher than a reference value RTE. If the engine temperature TE is lower than the reference value RTE, the control circuit **80'** opens the first solenoid valve **70** for a predetermined time t. Otherwise, the control circuit **80'** opens the first solenoid valve **70** if it is closed, whereas it opens the second solenoid valve **117** for a predetermined time t so as to retard fuel-injection timing if the first solenoid valve **70** is open. These operations are repeated until the engine is stopped after the engine is started.

When the engine is off, the cam disc **23** remains still and exerts no force on the roller ring **26**, whereas the fuel pressure in the chamber **59** is equal to that in the chamber **60**. Thus, the piston **58** is moved to the right with respect to the cylinder **52** under the force of the spring **62** and the cylinder **52** is moved to the left with respect to the casing **51** under the force of the spring **57** so that the drive pin **63** is held in its neutral position as shown in FIG. **15A**. When the engine is started, the cam disc **23** rotates and exerts forces on the roller ring **26** such as to move the piston **58** to the right through the drive pin **63**. At this time, however, the control circuit **80'** provides a signal to the first solenoid valve **70** which thereby remains closing the first release passage **55** to prevent rightwrd movement of the cylinder **52** so as to provide an injection advance corresponding to the length l as shown in FIG. **15B** which is predetermined for engine starting.

When the engine is warmed to some extent, the control circuit **80'** provides a signal to the first solenoid valve **70** which thereby gradually opens the first release passage **55** and eventually opens it fully in accordance with engine warming conditions. As a result, the cylinder **52** moves to the right against the force of the spring **57** until it abuts against the shoulder **73** of the casing **51** as shown in FIG. **15B**. Thereafter, the fuel pressure in the chamber **59** increases in proportion to increase in engine rotational frequency, causing leftward movement of the piston **58** to rotate the roller ring **26** in a direction opposite to the direction of rotation of the cam disc **23** so that fuel-injection timing is automatically advanced in accordance with engine speed. The obtained injection advance is read by the control circuit **80'** which opens the second solenoid valve **117** to decrease the fuel pressure in the chamber **59**, causing rightward movement of the piston **58** so as to retard to the fuel-injection timing to an optimum value in accordance with engine operating conditions if the obtained injection advance is higher than a reference value. Accordingly, it is preferable to design the injection advance device such as to provide an injection advance slightly higher than the optimum value when the second solenoid valve **117** is closed. This may be made by using a weak spring as the spring **62**.

Referring to FIGS. **19A** and **19B**, there is shown a fourth embodiment of the present invention which is substantially similar to the second embodiment except that a third passage **120** is provided for communication between the chambers **53** and **59** when the cylinder **52** is near its rightmost position. The third passage **120** includes a hole **121** formed in the cylinder **52** and a recess **122** formed in the inner surface of the casing **51**.

FIG. **20** shows a circuit **80"** for driving the solenoid valve **70** wherein the reference numeral **74** an engine key switch. The valve drive circuit **80"** receives various signal indicative of atmospheric temperature, engine temperature, engine speed, engine running time, and other engine operating conditions, and also an injection advance indicative signal from an injection advance detector (not shown) adapted to monitor the injection advance from the displacement of the injection nozzle needle valves and the fuel pressure through the injection passages for closing and opening the solenoid valves **70** so that an optimum injection advance can be obtained in accordance with engine operating conditions.

When the engine is off, the cam disc **23** remains still and exerts no force on the roller ring **26**, whereas the fuel pressure in the chamber **59** is equal to that in the chamber **60**. Thus, the piston **58** is moved to the right with respect to the cylinder **52** under the force of the spring **62** and the cylinder **52** is moved to the left with respect to the casing **51** under the force of the spring **57** so that the drive pin **63** is held in its neutral position as shown in FIG. **19**A. When the engine is started, the cam disc **23** rotates and exerts forces on the roller ring **26** such as to move the piston **58** to the right through the drive pin **63**. At this time, however, the solenoid valve **70** remains closed closing the first release passage **55** to prevent rightward movement of the cylinder **52** so as to provide an injection advance corresponding to the length l as shown in FIG. **19**A which is predetermined for engine starting.

When the engine is warmed to some extent, the solenoid valve **70** gradually opens the first release passage **55** and eventually opens it fully in accordance with engine warming conditions. As a result, the cylinder **52** moves to the right against the force of the spring **57** until it abuts against the shoulder **73** of the casing **51** and at the same time communication is established through the third passage **120** between the chambers **59** and **53**.

For example, if the injection advance is lower than an optimum value, the solenoid valve **70** is closed to increase the fuel pressure in the chamber **53** so as to move the cylinder **52** to the left while at the same time to increase the fuel pressure in the chamber **59** so as to move the piston **58** to the left. When the communication between the hole **121** and the recess **122** is broken some time later, the piston **58** moves to the left in a similar manner as described above. If the injection advance is higher than an optimum value, the solenoid valve **70** is opened so as to retard the fuel-injection timing as a manner contrary to the above. Accordingly, it is possible to hold fuel-injection timing at an optimum value in accordance with engine operating conditions.

FIG. **21** is a graph showing the range of variations in injection advance obtained by this embodiment wherein the lower limit line indicates zero injection advance and the upper limit line indicates obtained by the injection advance device of FIGS. **19**A and **19**B. It can be seen from FIG. **21** that an injection advance corresponding to the length l can be obtained during engine starting and the control range is over the full range of movement of the drive pin **63**.

Referring to FIGS. **22**A and **22**B, there is illustrated a fifth embodiment of the present invention which is substantially similar to the structure of FIGS. **19**A and **19**B except that the third passage **120** is eliminated and instead a fourth passage **130** is formed in the casing **51** for communication of the pump chamber **15** with the chamber **53**. The fourth passage **130** has therein an orifice **131** and a check valve **132** adapted to allow only the flow of fuel to the chamber **53**.

When the engine is off, the cam disc **23** remains still and exerts no force on the roller ring **26**, whereas the fuel pressure in the chamber **59** is equal to that in the chamber **60**. Thus, the piston **58** is moved to the right with respect to the cylinder **52** under the force of the spring **62** and the cylinder **52** is moved to the left with respect to the casing **51** under the force of the spring **57** as shown in FIG. **22**A.

When the engine is in operation, the cam disc **23** rotates and exerts forces on the roller ring **26** such as to move the cylinder **52** to the right through the drive pin **63**. At this time, however, the fuel pressure increases in the chamber **23** to prevent rightward movement of the piston **58**. For example, if the sensed injection advance is lower than a reference value, the control circuit **80**" closes the solenoid valve **70** to increase the fuel pressure in the chamber **53** so as to move the cylinder **58** to the left. Accordingly, it is possible to control the injection advance up to a value corresponding to the length l.

Although the automatic injection advance device is in a state as shown in FIG. **22**B at the time when the engine is stopped, the reaction force exerting on the drive pin **63** disappears so that the cylinder **52** is moved leftwards to a position as shown in FIG. **22**B.

FIG. **23** is a graph showing the range of variation of the injection advance obtained by the automatic injection advance device of this embodiment.

FIG. **24** shows a modified form of the automatic injection advance device of FIGS. **22**A and **22**B wherein a check valve **140** is provided in a passage **141** formed in the right-hand end of the cylinder **52** for communication between the chambers **59** and **53**. The check valve **140** comprises a valve element **142**, a spring **143**, and a valve housing **144**. An orifice **146** is provided in the passage **141**. For example, if the solenoid valve **70** is opened in a state as shown in FIG. **24**, the fuel pressure in the chamber **59** rapidly falls since the fuel pressure in the chamber **59** falls at the same time when the fuel pressure in the chamber **53** falls and an orifice **146** is normally provided in the passage **61**. This is effective to move the cylinder **52** with a higher response to the operation of the solenoid valve **70**.

It is to be understood that the scope of the invention is not to be restricted to the embodiments above described but rather, in view of the numerous modifications and changes which will readily occur to those skilled in the art, the scope of the invention is set forth in the appended claims.

What is claimed is:

1. In a fuel injection pump for use in a diesel engine, said fuel injection pump including a pump housing defining an interior pump chamber, said housing containing a feed pump for supplying fuel under pressure substantially proportionally to engine speed to said pump chamber, and a fuel-injection timing control member movable to determine a fuel-injection timing corresponding to its position, an injection advance device comprising:

(a) a casing fixed to said pump housing;

(b) a cylinder slidably located in said casing to form first and second chambers at the respective ends of said cylinder, said first chamber being in communication with said feed pump inlet side and said second chamber being in communication through a release passage with said feed inlet side;

(c) first spring means located in said second chamber for urging said cylinder toward said first chamber so as to advance the fuel-injection timing;

(d) a piston slidably located in said cylinder to form third and fourth chambers at the respective ends of said piston, said third chamber communicating with said feed pump inlet side, said fourth chamber communicating with said pump chamber, said piston being drivingly connected to said control member;

(e) second spring means located in said third chamber for urging said piston towards said fourth chamber; and

(f) valve means provided in said release passage for interrupting communication between said second chamber and said feed pump inlet side so as to prevent said cylinder from moving towards said second chamber in response to at least one engine operating parameter.

2. An injection advance device according to claim 1, wherein said release passage is defined by a groove formed in the outer surface of said cylinder.

3. An injection advance device according to claim 1, wherein said valve means comprises an orifice provided in said release passage.

4. An injection advance device according to claim 1, wherein said valve means comprises a temperature responsive valve adapted to open said release passage above a predetermined temperature.

5. An injection advance device according to claim 4, wherein said temperature responsive valve comprises a poppet valve provided in said release passage, a return spring urging said poppet valve to its closed position, and a thermostat element adapted to expand so as to push said poppet valve to its open position against the force of said return spring in responsive to an increase in temperature.

6. An injection advance device according to claim 4, wherein said temperature responsive valve comprises a poppet valve provided in said release passage, a return spring urging said poppet valve to its closed position, and a bimetal element adapted to expand so as to push said poppet valve to its open position against the force of said return spring in response to an increase in temperature.

7. An injection advance device according to claim 1, wherein said valve means comprises a solenoid valve, and which further comprises valve control means for controlling the opening of said solenoid valve in accordance with various engine warming condition indicative factors and the injection advance with which fuel is injected to said engine.

8. An injection advance device according to claim 7, which further comprises a third release passage connecting said pump chamber to said second chamber when the fuel pressure in said pump chamber is above a predetermined value.

9. An injection advance device according to claim 8, wherein said third release passage is made up of a port formed in said cylinder and connected to said fourth chamber and a recess formed in the inner surface of said casing for connection to said port when said cylinder is near the end of said casing facing said second chamber.

10. An injection advance device according to claim 8, wherein said third release passage is formed in said casing and provided therein a check valve for allowing only the flow of fuel toward said second chamber.

11. An injection advance device according to claim 8, wherein said third release passage is formed in the end wall of said cylinder facing said second chamber and provided therein a check valve for allowing only the flow of fuel toward said second chamber.

12. An injection advance device according to claim 7, which further comprises a second release passage connecting said fourth chamber to said first release passage, a second solenoid valve provided in said second release passage, and valve control means for controlling the opening of said first and second solenoid in accordance with various engine warming condition indicative factors.

13. An injection advance device according to claim 12, wherein said second release passage is made up of a first port formed in said casing and connected to said first release passage and a second port formed in said cylinder connected to said fourth chamber, and said first and second ports positioned for communication of said fourth chamber with said first release passage when said piston is near the end of said cylinder facing said second chamber.

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